DOCUMENT RESUME

ED 339 885 CE 059 834

AUTHOR Yunke, P.; And Others
TITLE Mold Die Making. 439-322/324.
INSTITUTION Milwaukee Area Technical Coll., Wis.
SPONS AGENCY Wisconsin State Board of Vocational, Technical, and Adult Education, Madison.
PUB DATE 90
NOTE 217p.; For a related curriculum guide, see CE 059 833.
PUB TYPE Guides - Classroom Use - Instructional Materials (For Learner) (051) -- Guides - Classroom Use - Teaching Guides (For Teacher) (052)

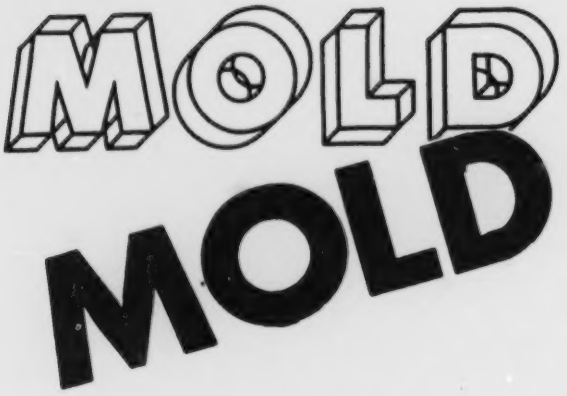
EDRS PRICE MF01/PC09 Plus Postage.
DESCRIPTORS *Electronic Control; *Machine Tools; Occupational Safety and Health; Technical Institutes; *Tool and Die Makers; Trade and Industrial Education; Two Year Colleges
IDENTIFIERS Die Cutting; *Electrical Discharge Machine; Electrodes; *Moldmaking

ABSTRACT

Each unit in this curriculum guide on mold die making contains an introduction, objectives, materials required, lessons, space for notes, figures, and diagrams. There are 10 units in this guide: (1) introduction to Electrical Discharge Machining (EDM); (2) EDM principles; (3) the single pulse; (4) EDM safety; (5) electrode material; (6) electrode holders; (7) flushing; (8) the machine controls; (9) planning a cut; and (10) set up and operation. Four appendices are included: (1) overcut, arc duration, percent on-time and cutting speed graphs; (2) arc duration multiplier chart; (3) area formulas; and (4) project prints. (NLA)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED339885



MOLD DIE MAKING

439-322/324

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☑ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

L Harmatuck

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

By: P. Yunke, J. Miller, R. Boyle,

D. Marlow, R. Hartzheim

matc
Milwaukee Area Technical College
Industrial Division

CE059834

BEST COPY AVAILABLE

ACKNOWLEDGMENTS

We would like to thank the following companies for their contributions in the development of this manual.

Hansvedt Industries, Inc.

System 3R International

Poco Graphite, Inc.

A special acknowledgment to Dr. Carol Spencer, Dean of the Technical and Industrial Division, and John Stilp, Associate Dean of the Technical and Industrial Division at Milwaukee Area Technical College for their support during this project.

439-322 & 324

MOLD DIE MAKING

TABLE OF CONTENTS

	PAGE
Acknowledgments	1
Table of Contents	2
	3
UNIT 1	
Introduction to EDM	1-1
1) Objectives	1-1
2) EDM Applications	1-4
UNIT 2	
EDM Principles	2-1
1) Objectives	2-1
2) EDM Machine Components	2-1
3) EDM Terms	2-3
4) Process Variables	2-9
5) Process Variable Example	2-11
UNIT 3	
The Single Pulse	3-1
1) Objectives	3-1
2) Introduction	3-1
3) One Complete Pulse Cycle	3-1
UNIT 4	
EDM Safety	4-1
1) Objectives	4-1
2) By Products of EDM	4-1
3) Explosion Potential	4-2
4) Gas Fire	4-4
5) Oil Fire	4-4
6) Electrical Danger	4-5
UNIT 5	
Electrode Material	5-1
1) Objectives	5-1
2) Types of Electrode Material	5-1
3) Key Factors For Selection	5-3

		PAGE
UNIT 6		
	Electrode Holders	6-1
	1) Objectives	6-1
	2) Introduction	6-1
	3) Applications of Various Holders	6-2
	4) Clamping Devises	6-6
	5) Calibration of Clamping Systems	6-9
	6) Other Mounting Methods	6-10
UNIT 7		
	Flushing	7-1
	1) The purpose of Flushing	7-1
	2) Types of Flushing	7-2
	3) Flushing Pressure	7-7
	4) Flushing Attachments	7-8
	5) Flushing Control Valves	7-9
UNIT 8		
	The Machine Controls	8-1
	1) Introduction	8-1
	2) Power Supply Controls	8-2
	3) Monitor Area of Power Supply	8-5
	4) Machine Control Panel	8-7
	5) Stabilizing Controls	8-11
UNIT 9		
	Planning a Cut	9-1
	1) Introduction	9-1
	2) Over Cut	9-1
	3) Sizing the Electrode	9-3
	4) Example #1 Single Electrode Job	9-4
	5) Example #2 Multiple Electrode Job	9-9
	6) Example #3 Stepped Electrode	9-14
UNIT 10		
	Set Up and Operation	10-1
	1) Objectives	10-1
	2) Start Up	10-1
	3) Workpiece Setup	10-2
	4) Power Supply Controls	10-5
	5) Machine Controls	10-6
	6) Filling the Tank	10-6
	7) Starting a Cut	10-7
	8) Alarms	10-9
Appendix 1	Overcut, Arc duration, % On-Time, and Cutting Speed Graphs	4
Appendix 2	Arc Duration Multiplier Chart	44
Appendix 3	Area Formulas	46
Appendix 4	Project Prints	48

UNIT 1

INTRODUCTION TO EDM

OBJECTIVES

After completion of this unit the student will be able to:

1) define the term EDM.
2) list the advantages of EDM over conventional machining.
3) describe various applications of EDM.

WHAT IS EDM?

The letters EDM stand for electrical discharge machining. Electrical discharge machining is machining that is caused by an electrical pulse applied across a gap between an electrode and a workpiece. This pulse causes a spark discharge to occur and material to be removed from both the electrode and the workpiece.

EDM APPLICATIONS

EDM has various applications in the tool and die shop. They are many and varied. EDM has definite advantages over conventional machining for both mold making and stamping die building. The following list provides examples of how EDM is utilized in the tool and die shop. It also demonstrates the advantages of EDM over conventional machining.

1) Production of cavities for molds, draw dies, die cast dies, forging dies, extrusion dies, and wire draw dies.

2) Eliminating sectionalizing of the above mentioned dies allowing for solid construction.

3) Accurate machining of deep slots and pockets without the problem of tool deflection.

4) Sharp detail can be machined to high surface finish requirements (a 20 micro inch finish). Fine surface finishes do require extra time.

5) Elimination of heat treatment problems because details can be machined after heat treatment. (EDMing after heat treat is actually more efficient because the EDM process works better on materials that have had internal stresses relieved.)

6) To do machining that could not be done conventionally. Threads can be burned into hardened workpieces (CNC machine or special attachment required).

7) It is possible to remove broken taps, drills, or other hardened tooling without damaging the workpiece.

8) Rework can be done on hardened tools.

9) Parting lines can be matched perfectly using one half fo the mold as an electrode and burning the two halves of the mold together.

10) Any metal can be cut no matter how hard or brittle if ti has a low resistance and conducts electricity. This is especially useful on those materials considered the be impossible to machine via conventional methods.

11) There are no machining forces so it is possible to machine very thin sections without distortion.

12) EDM is automatic machining. You need only to make the setup, and adjust the cut, the machine can then run unattended.

13) Machining with EDM is virtually burr free. (There is a recast layer that forms, but this is easily removed.)

14) EDM can reach the hard to reach areas in deep pockets or slots that you cannot reach with conventional machining.

15) Miniature work can be performed. It is possible to produce a hole as small as .002" in diameter.

As you can see from the list EDM is a very useful tool. The applications are numerous and still growing. Once a Tool Maker has a good understanding of the capabilities of the machine they will be able to use their imagination and create new applications enabling more efficient use of the machine tool.

Notes:

UNIT 2

EDM PRINCIPLES

OBJECTIVES

After completing this unit the student will be able to:

1) describe the various components that make up the EDM machine
2) list the process variables.
3) describe how the process variables affect the machining process and the piece part.
4) describe the functions of the dielectric fluid.
5) define the terms associated with EDM.

THE EDM MACHINE

The EDM machine consists of four basic parts. They are:

1. The machine tool
2. The machining head
3. The power supply
4. The fluid system

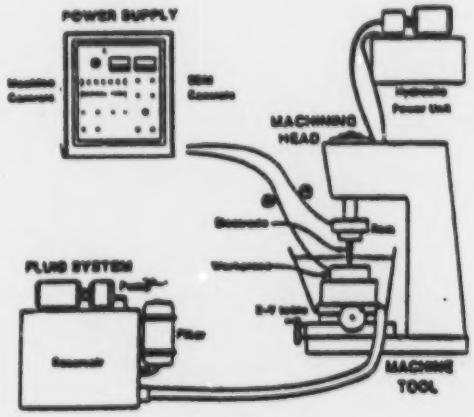


Figure 2-1
EDM Machine basic components

The machine tool is the body of the machine, this is normally a cast base and column. It will have an area for the workpiece to be mounted (this is the work tank). There will be a positioning system to allow for positioning of the workpiece. (The positioning system on our machine is equipped with ball screws.) A hydraulic unit is used for controlling the servo on the head of the machine (this will be discussed later).

The machine head is the area of the machine that provides the area for mounting the electrodes. The head on our EDM machine has T-slots for securing the various electrode attachments.

The power supply is a DC square wave generator. This supplies the power to the electrode. This power supply is similar to that of a DC arc welder with the difference being that the electrical pulses on the welder are on 100% of the time and the electrical pulses of the EDM machine are turned on and off repeatedly.

The fluid system provides the supply of dielectric fluid for the work tank. This system consists of a reservoir, a pump, and filters. The filters clean the chips out of the fluid so that tank can be supplied with clean fluid to allow for efficient operation. The filters on our EDM machine clean down to .5 microns (nominal).

UNIT 2

EDM BASICS

The following is a list of terms and definitions that are common to EDM. These terms are used often and you should be familiar with them.

Amperage: The electrical energy produced by the power supply. The more amperage used the faster the machine will cut and the rougher the finish. (see figure 2-2) There are two types of amperage that are referred to, they are:

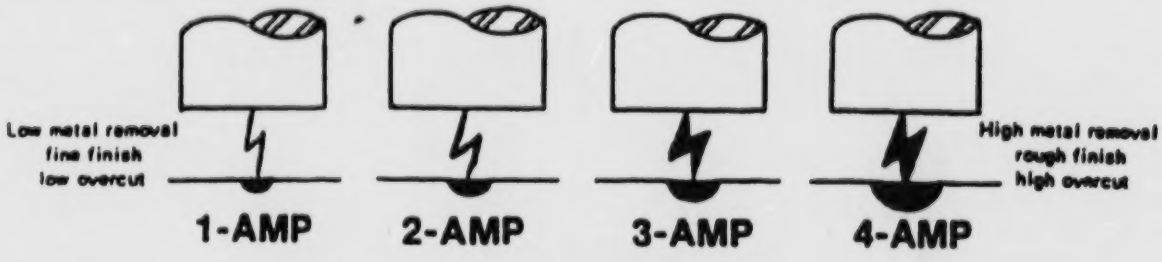


Fig. 2-2 Amperage

Average amperage: The portion of the peak amperage that is being used. This is a product of the efficiency setting and the % on-time settings.

Peak amperage: (also referred to as peak current) The total amount of amperage available for each pulse or discharge.

Arc duration: The length of the pulse in micro-seconds. (see figure 2-3) Arc duration affects the surface finish and the overcut. Longer arc durations produce rougher surface finishes than short arc durations. (see figure 2-4) For any one power setting there is only one arc duration that will provide "no wear" machining.

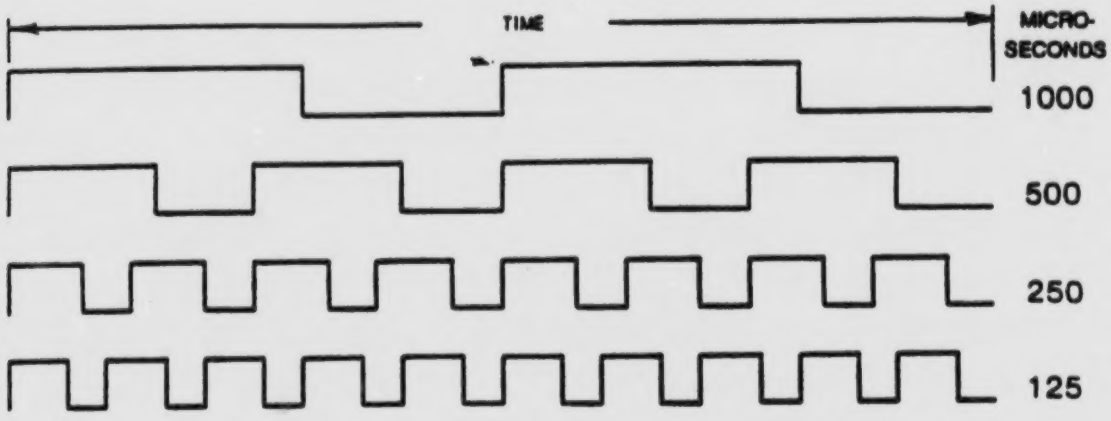


Fig. 2-3 Arc Duration in micro-seconds

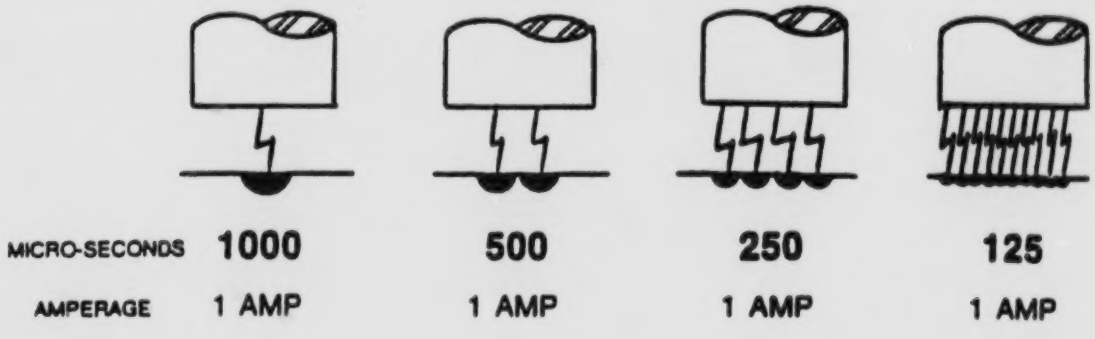


Fig. 2-4 Arc Duration - Affect on surface finish and overcut

Dielectric Fluid: An insulating fluid that must break down when a specific voltage is reached between the electrode and the workpiece. Dielectric fluid also serves another purpose, that is to solidify the molten particles that are produced by the EDM process and wash them away.

Electrode: A piece of material that has low resistance and good electrical conductivity that is used as a cutting tool in an EDM machine. It is made in the shape of the desired detail to be machined.

Flushing: The most important factor for efficient EDM machining. Flushing is the removal of excess material or chips that are produced during the machining process. Without good flushing EDM is very difficult if not impossible. Different flushing methods will be discussed later.

OVERCUT: The difference in size between the electrode and the workpiece that is the result of the discharges. On a round electrode it is the difference in the diameter of the electrode and the size of the hole it produces in the workpiece. It is always expressed in thousandths per side. (see figure 2-6) Also refer to figure 9-1 on page 9-2.

Gap: The area between the electrode and the workpiece where the electrical discharge takes place. (see figure 2-6) The controlled arcing that takes place across the gap causes the melting of small particles and thus material removal. On a cut that takes place with a straight Z axis movement it is the space between the bottom of the electrode and the workpiece.

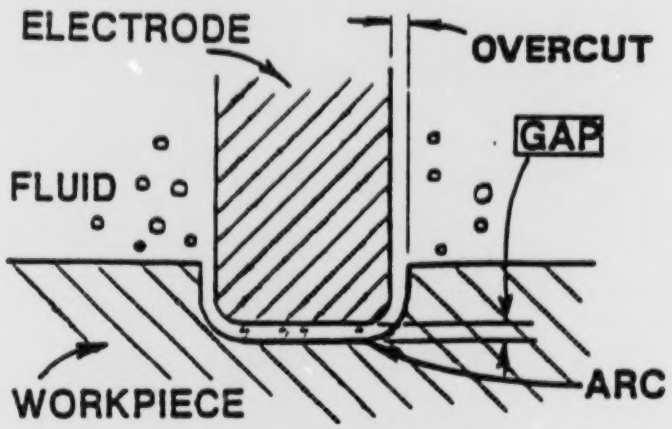


Fig. 2-6 Gap

Gap power: The electrical energy present at the electrode. **Whenever gap power is on nothing inside the tank should not be touched!!!**

No-wear: An amount of wear of 1% or less. This is only possible with one particular arc duration for any one power setting (peak current setting) No-wear does not mean that no material is

removed from the electrode rather the material that is removed from the electrode is replaced or re-plated with material from the workpiece. You will note that the area of the electrode used during a cut will turn grey. This is do to the re-cast or re-plated material from the workpiece.

Off-time: The amount of time between electrical pulses. This time is useful for flushing away the EDM chips. This does not affect the surface finish or the amount of overcut.

On-time: The length of time the electrical pulses are left on. (see figure 2-7) This does not affect the amount of overcut or surface finish. This however does have a direct affect on electrode wear if not set correctly. Because % on-time affects average amperage it is possible with too high of an on-time setting to over power an electrode and greatly increase the amount of wear.

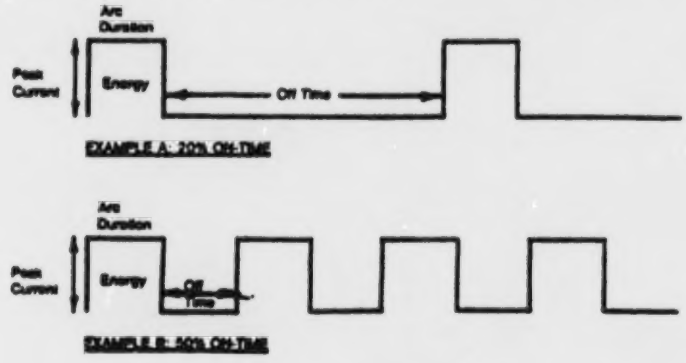


Fig. 2-7 % On-Time

Pulse: The flow of electrical energy (current) between the electrode an the workpiece. (see figure 2-8) There can be over 100,000 pulses per second, but never more than one pulse occurring at any one time.

The electrical energy required for machining is produced by the power supply in a continuous flow of pulses.

Fig. 2-8 Pulse

Wear: The ratio of electrode material to workpiece material that is removed during the EDM process. (see figure 2-9 and 2-10.) e.g. If you cut .500 deep into a piece of steel and lose .050 off of the end of your electrode. .050/.500=.1 or 10% wear.

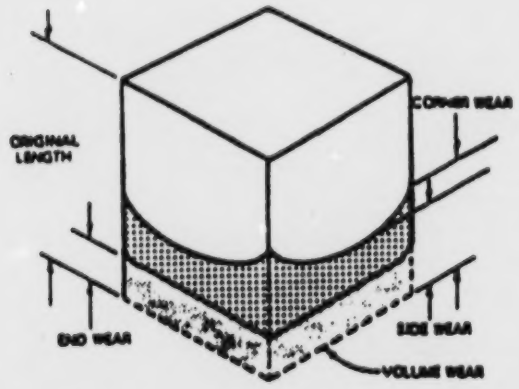
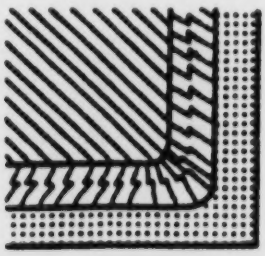


Fig.2-9 Wear



A higher concentration of discharges at the corners increases wear in these areas

Fig. 2-10 Corner Wear

UNIT 2

THE PROCESS VARIABLES

There are three process variables that have an affect on EDM speed, finish, and/or overcut. These variables are controlled by the operator. The factors that help the operator determine how these variables are set are the type of work being done, the size of the electrode, the finish required, and the type and efficiency of the flushing being used.

Peak Current (amperage)

The first process variable is peak current. The peak current that is selected depends on the size of the electrode being used. You are able to apply more amperage to an electrode that has a larger surface area. Peak current has a direct affect surface finish, the overcut that is produced, and the speed at which the cut takes place.

It is possible to put more amperage into an electrode than its surface area will allow. This depends on the job being done and the condition you would like to have your electrode in after the job is complete. Over powering and electrode will cause excessive wear. You may also have a problem adjusting the cut. You may at times decide to over power an electrode to get the job done more quickly. This is often done when the EDM machine is used for things like tap removal or "hogging out" material.

In these applications the amount of wear is not important what is important is to remove the material as quickly as possible.

Arc Duration

The next process variable is arc duration. Like peak current arc duration also affects surface finish, overcut, and the speed of the cut. The arc duration is selected with regards to the peak current being used and the amount of wear that is acceptable for a particular job. Different arc durations used with the same peak current will cause a different amount of overcut (refer to figure 2-4) and will cause a different amount of wear. If no wear (1% wear or less) is required there is only one arc duration setting for any one power setting that will allow this condition to exist.

% On-Time

The last process variable is per cent on-time. Per cent on-time **does not affect** over cut and surface finish. Per cent on-time affects the stability and speed of the cut. Once you have selected a peak current and an arc duration for a particular job you normally leave them set. Per cent on-time is a variable that you can adjust to stabilize the cut. You must look at the charts and **if low wear is important be sure you do not use more per cent on-time than the size of your electrode will allow.**

When the per cent on-time is turned up you will notice that the average amperage will also increase.

The by product of per cent on-time is off-time. Off time is the time that the pulses are turned off. This is the time when flushing can occur. If a cut is having flushing problems in the gap a reduction of on-time (an increase in off time) may stabilize it.

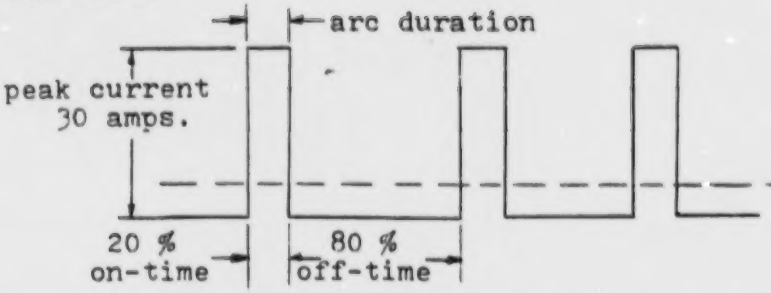
The illustration on the following page shows three different EDM cuts. The peak current and the arc duration are exactly the same for all three examples. The difference in the three cuts is the per cent on-time. Notice that the average amperage goes up directly with the per cent on-time. Look at the illustrations and answer the following questions:

1. Which cut will produce the best surface finish?

2. Which cut will be fastest?

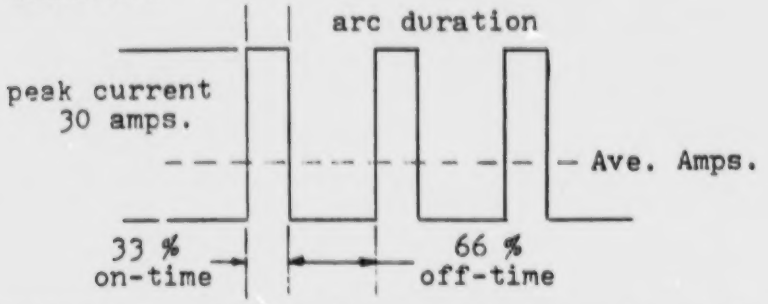
(Keep in mind how each process variable affects the cut)

EXAMPLE-1



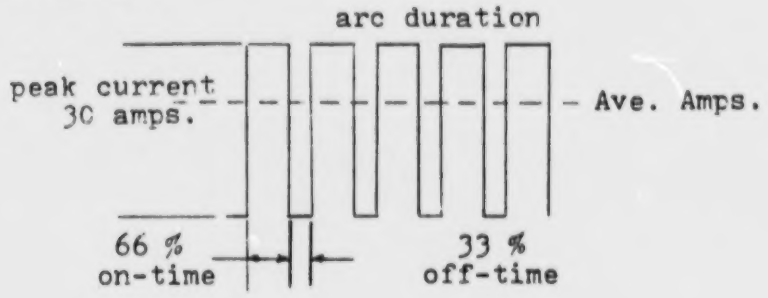
.20 (on-time)
X 30 (peak amps.)
6 ave.amps.

EXAMPLE-2



.33 (on-time)
X 30 (peak amps.)
10 ave. amps.

EXAMPLE-3



.66 (on-time)
X 30 (peak amps.)
20 ave. amps.

To answer the questions on the previous page you need to know what each process variable affects. Peak current (amperage) and arc duration affect surface finish, overcut, and speed.

The peak current and arc duration did not change. Since these are the two variables that affect surface finish and they did not change we can conclude that the surface finish would be the same for all three examples.

The second question regarding which example would cut the fastest can be answered following the same type of procedure. Since peak current and arc duration did not change we do not have to consider their affects on the cut. Per cent on-time did change. Per cent on-time does affect speed and stability. The higher the per cent on-time the higher the average amperage. The higher average amperage the faster the cut. So the fastest cut would be achieved by example #3.

Notes:

UNIT 3

THE SINGLE PULSE

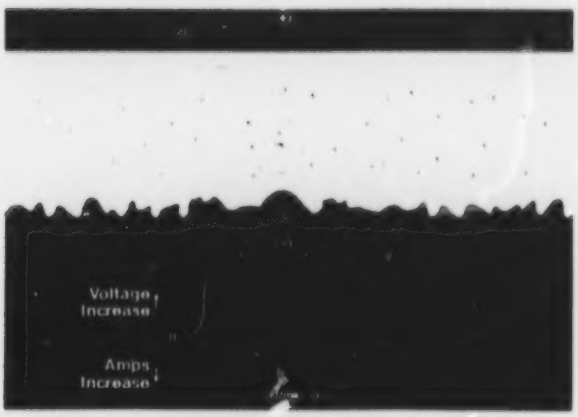
OBJECTIVES

After completing this unit the student will be able to:

1) describe what takes place between the electrode and the workpiece during one complete pulse cycle.

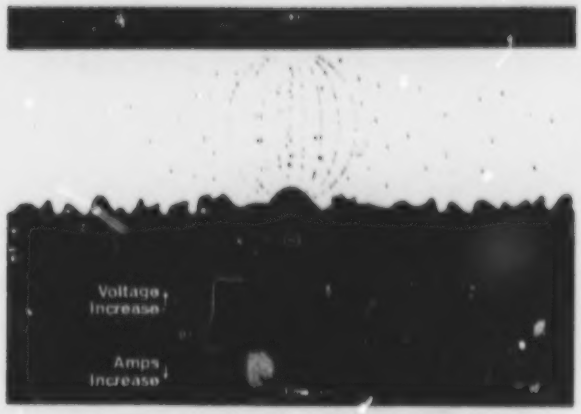
INTRODUCTION

Although what takes place in the gap during the discharge of an electrical pulse is complicated a basic understanding of the process will benefit the operator. The following description and illustrations represent the current theory of what happens during one pulse cycle in the EDM machining process.

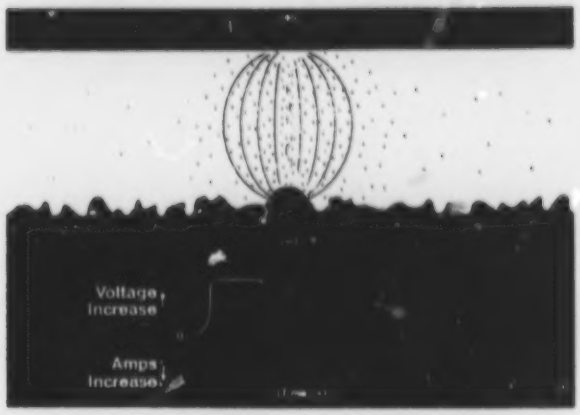


A charged electrode approaches a workpiece(on-time). The insulating dielectric fluid is between the electrode and the workpiece. The voltage is increasing but the electrical current is zero.

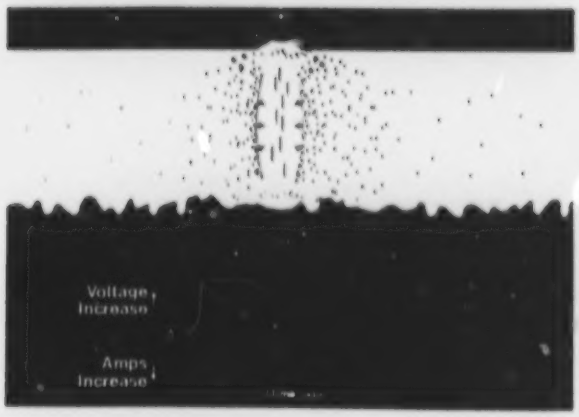
BEST COPY AVAILABLE



The ionization of the fluid continues causing the insulating properties of the dielectric fluid to break down further. The voltage is peaked but the current is still at zero.

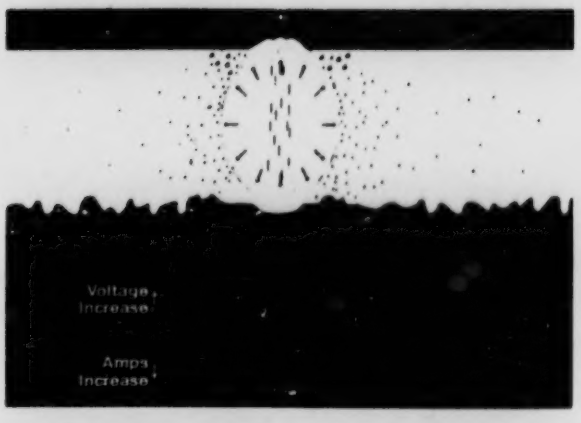


A flow of current begins as the insulation of the dielectric fluid is decreased even more. The voltage begins to drop off.

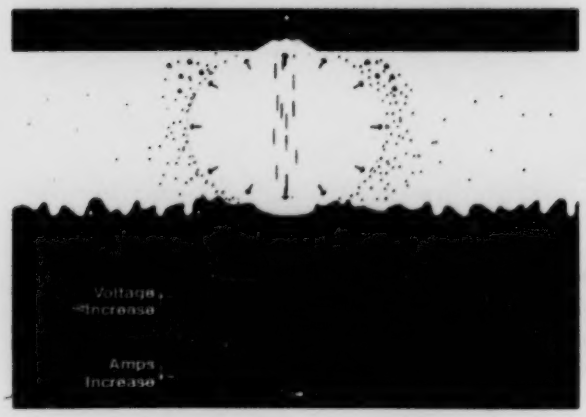


The current increases and the heat that is generated causes the fluid to become vaporized. A discharge column begins to form. The voltage continues to drop.

BEST COPY AVAILABLE



The current continues to rise and the vapor bubble expands. The column of current also increases in size. The voltage continues to drop.

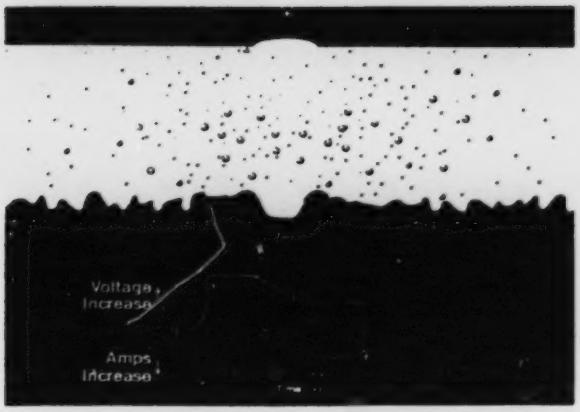


The area of metal under the discharge column is in a molten state. The current is at its maximum. A tremendous amount of heat and pressure are in the vapor bubble.

The pulse is terminated (off-time). The vapor bubble is collapsed do to the decrease in temperature resulting from the current being shut off. The molten metal is expelled from its crater.

BEST COPY AVAILABLE

Dielectric fluid flows in and flushes away the debris. The molten metal that is not expelled from the crater cools and become the recast layer.



The vapor bubble is completely gone and replaced by dielectric fluid. Micro spheres of solidified molten metal are suspended in the fluid. One complete cycle is over and another is ready to begin.

The sequence that has just been described is for just one pulse. There is never more than one pulse occurring at any instant of time (as the pulse takes place at the closest point between the electrode and the workpiece and there can only be one closest point). There can be over 100,000 pulses per second.

BEST COPY AVAILABLE

Notes:

UNIT 4

EDM SAFETY

OBJECTIVES

After completing this unit the student will be able to:

1) describe what to do in the event of an EDM gas fire.
2) describe what to do in the event of an EDM fluid fire.
3) describe the conditions that could cause an EDM explosion.

By Products of EDM Machining

When the EDM process takes place under the dielectric fluid several things take place. First of all particles are produced from both the electrode and the workpiece. These are in the form of micro sized chips of both the electrode material and the workpiece material.

Gases

Because of the extremely high temperatures at which the machining action takes place some of the dielectric oil (if mineral oil) is converted into hydrocarbon gases. The content of the gases is as follows:

Ethylene - 40% Ethane and propane - 11%

Acetylene - 24% Methane - 9% Unidentified - 16%

As you can see from the different gases that are present there is a definite potential for a gas fire.

Free Carbon

Free carbon (ash) is also found as a by product of the EDM process. This is produced from the reaction of the oil and the high temperatures at the gap. These temperatures actually crack the oil and form the ash.

Smoke

Smoke is formed during the operation and is normally taken up with some sort of smog collection device.

Heat

Heat is produced at the gap do to the violent reaction of the electrical pulses impacting the workpiece. The actual temperature at the gap can be as high as 20,000 degrees F.

Explosion Potential

An explosion can occur when you have a combination of four elements:

1) a confined space
2) presence of oxygen
3) presence of CH gases (hydrocarbon gases)
4) source of ignition

You can tell after examination of the by products of EDM machining that all of the elements needed for an explosion are present. Care must be taken to prevent such an accident.

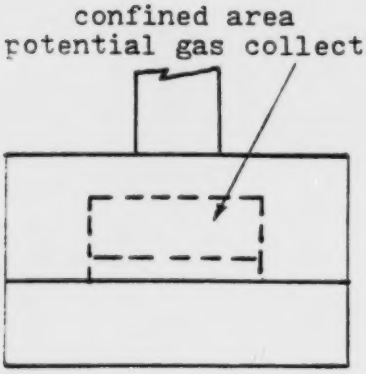


Fig.4-1

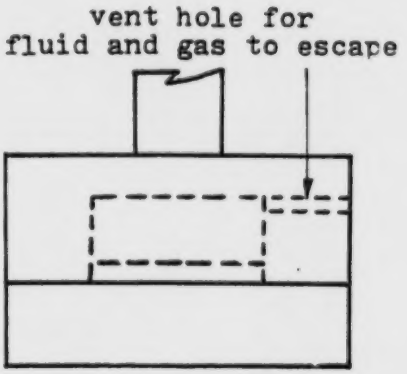


Fig. 4-2

When an electrode like the one in figure 4-1 is used there is a definite potential for an explosion. This type of electrode has everything needed for an explosion. It has a confined area, gas, and sparks to supply ignition.

The potential for an explosion can be eliminated by the following. All that is needed to eliminate the potential for an explosion in this case is to drill a vent hole in the top of the electrode at the highest point (see figure 4-2). The hole must be large enough to allow the gases and a small amount of oil to escape. We have now eliminated the confined area and made for a safe operation.

Gas Fire

When the workpiece is not sufficiently covered with dielectric fluid it is possible and probable that a gas fire will occur. The previously mentioned gases are flammable and care must be taken so they do not have a chance to ignite. Always be sure that the oil level sensing device is working properly and that the top of the workpiece is completely covered with dielectric fluid. This will keep the supply of oxygen away from the gap and not allow a fire to start.

If a gas fire does start you should follow these procedures:

1) <u>turn off</u> the gap power (the fire should go out *)

2) raise the oil level and resume the machining operation

* If the fire does not go out it is an oil fire.

Oil Fire

The dielectric oil can also ignite. This normally happens when a gas fire is allowed to burn. When a gas fire is not detected and allowed to burn it will heat the oil to its flash point and start it burning. This is very dangerous especially when you consider that these machines are allowed to burn unattended over night.

You should always make sure that the level of the oil is sufficiently over the surface of the workpiece and that the oil level sensing device is working and properly located.

If an oil fire does occur you should follow these procedures:

1) **turn off** the gap power
2) **smother** the fire with a CO foam

There are commercially made fire extinguishers available for EDM machines. They have heat sensing devices and will automatically discharge if a fire is present.

Electrical Danger

The other danger that is associated with EDM machines deals with the electrical current. There is a great deal of energy used in the gap of the EDM machine and it should be treated with respect.

You should **never touch** the workpiece ,the machine table, the machine head or the electrode when the **gap power is on.** You should also be sure that all of the safety guards are in place on the machine tool. The potential for electrocution should not be treated lightly. Again, **do not touch any portion of the machine inside the tank area when there is power to the gap!**

Notes:

UNIT 5

ELECTRODE MATERIAL

OBJECTIVES

After completing this unit the student will be able to:

1) list various electrode materials.
2) describe the uses for various types of electrode materials.
3) list the five factors that are used to select an electrode material.

TYPES OF ELECTRODE MATERIALS

There are several different types of electrode materials available for use on the EDM machine. Each type of material has specific properties that make it useful for certain applications. The following is a list that includes a brief description some of the more common electrode materials that are used.

Graphite: Graphite permits very fast cutting rates. When used with negative polarity it provides the fastest cutting of any of the electrode materials available. Graphite with negative electrode polarity will cut approximately twice as fast as graphite with positive electrode polarity. (When used with negative polarity you can expect a minimum of 15% wear.)

Typical surface finish that is obtainable with graphite is 32 RMS. There are new grades of graphite available that make it possible to obtain a surface finish of 10 RMS. The surface finish you obtain is dependent upon the grade of graphite you use.

Copper: A very popular electrode material when no wear machining is an important consideration. Copper will provide you better surface finishes than standard graphite.

Copper Tungsten: This is an excellent choice when machining carbide. Copper tungsten offers good low wear properties, works well for close tolerance work, and is also fast cutting (but not as fast as graphite). This material is also very expensive.

Steel: Steel is normally used when the two halves of the mold are mounted in the EDM machine and the parting lines are burned. Steel provides for slow stock removal rates.

Brass: Brass is a very fast cutting electrode material but it also has a very high wear factor. Not normally your first choice for electrode material.

Silver Tungsten: This is another choice for machining carbides. This material is more expensive than copper tungsten but does offer higher metal removal rates.

The list shown gives a sample of the electrode materials that are available for use in EDM. The list can be further divided by grades for each type of material.

KEY FACTORS WHEN CHOOSING AN ELECTRODE MATERIAL

In the shop it is important to select the correct electrode material for a given job. Selecting the correct material can mean the difference between successful completion and failure. In the competitive world it can mean the difference between profit and loss. There are five factors that should be considered before choosing an electrode material.

Metal Removal Rate

Metal removal rate is expressed in cubic inches per hour. The importance here is the time required for EDMing the job. Metal removal rate does not just depend upon achieving an efficient cut at the machine but also choosing the correct material. A material that will cut efficiently and give you the other properties required for the job.

Wear Factor

Electrode wear is important in that it represents the electrode materials ability to hold a desired detail. If detail is unimportant then wear need not be a factor to consider. But when detail needs to be held you should consider that a material with a high wear potential will require more electrodes to be used to obtain the required result. In other words if a sharp corner is needed in a cavity and an electrode material with poor resistance to wear is selected then multiple electrodes will be required. When detail is important, a materials ability to resist wear is also important.

Surface Finish

The surface finish for EDM is in reality the size of the crater produced by the spark at a given setting. The smaller the creator the better the surface finish. Each electrode material (for that matter each grade of electrode material) will produce a specific quality of surface finish. All electrode materials are not capable of producing the same level of surface finish. When a fine surface finish is required it is important to select the proper electrode material.

Machinability

The ability of the electrode to hold the desired shape is directly related to its machinability. Square corners that are burr free, thin ribs, or fine engraving all require various properties in a material to ensure a quality electrode. The job that is being done needs to be analyzed and the material selected accordingly.

Material Expense

There is more to the cost of a material than just dollars per pound. Although in many cases that is the only thing considered. Material expense is a combination of the four previously discussed factors. The cost of the material alone can not be the only factor considered. A cheap material with a high wear factor is not a cheap material to use for a job that requires fine detail because of the machining cost of producing multiple electrodes. Likewise a cheap material that chips easily when being machined is not cost effective because of the scrap produced. Fabrication time, labor cost, and electrode wear all figure into what the electrode cost will finally be. The actual cost of the material is just a very small part.

The selection of a material for a job here at school is not as involved as in the Tool and Die shop. But these things should be kept in mind for future reference.

Notes:

UNIT 6

ELECTRODE HOLDERS

OBJECTIVES

After completing this unit the student will be able to:

1) identify various types of electrode holders
2) select the correct holder for a particular job
3) describe various methods for mounting electrode material

INTRODUCTION

As with any other machine tool operation for Tool and Die Making the set up is very critical. With a proper set up the rest of the job will fall into place. When we think of the set up on the EDM machine the one of the first things that we must consider is how are we going to hold the electrode. Keep in mind that the method used to hold the electrode must be repeatable for all electrodes for that job and also that we must be able to hold the electrode for fabrication (machining) and also hold the electrode in the EDM machine. If we expect that accuracy is to be maintained, these set ups must be repeatable.

As mentioned above the need for the electrode set up to be duplicated during fabrication and use is of primary importance. There are several systems available today that will allow identical setup to be made between various machine tools.

We use the 3R system. The 3R system allows repeatable set ups between many different types of machine tools and the EDM machine. This is done by utilizing a common shank for mounting the electrode to a common holder.

APPLICATIONS OF VARIOUS ELECTRODE HOLDERS

Electrodes can take on any shape imaginable. We must be able to mount any shape onto the electrode holder to facilitate burning.

The 3R shanks that are being discussed here all have an indexing pin so that electrode detail can be timed or oriented with the workpiece. Most also have the ability to supply through the electrode flushing.

Collet Type Holder

With the 3R system the electrode can be held in a collet type holder. (see figure 6-1) This type of holder will accommodate electrodes up to 1/2" in dia.. The collet is a concentrically closing flexible collet so non-standard sizes are held easily. The collet system also allows through the electrode flushing which is very useful.

Fig. 6-1 Collet Chuck

Plane Shank Holder

The plain shank holder (see figure 6-2) will accommodate many various shapes and sizes of electrodes. An electrode can be mounted by using any type of super glue and a set screw.

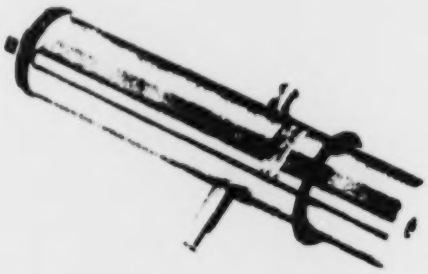


Fig. 6-2 Plane Shank

To prepare the holder for the set screw you must first drill a tap drill size hole in the end of the holder. This hole should go deep enough to connect with the flushing hole that is inside of the holder. This hole is just below the indexing pin. Now the hole can be tapped to a depth that will allow a portion of the set

screw to stick out. Install the set screw and drill a hole through it to allow for through the electrode flushing (if that is desired.

To prepare the electrode material for mounting face off an end and drill and tap the material with the thread size of the set screw. The electrode is then fastened onto the end of the holder using a small drop of super glue before tightening onto the set screw. (see figure 6-3) A volt ohm meter should now be used to check for continuity as the super glue is an insulator and we must be sure that the electrode material is not insulated from the holder.

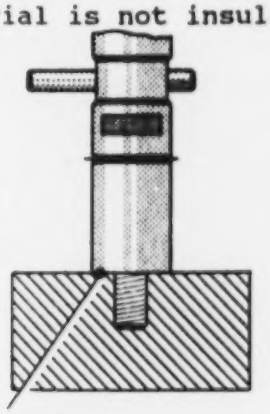


Fig. 6-3 Mounting on plane shank

Flanged Shank Holder

The flanged shank (see figure 6-4) is a holder that is used just like the plain shank. The difference here is with the large flange on the end this holder will support much larger electrodes.

Fig. 6-4 Flanged Shank

The method for mounting the electrode is different than the plain shank. With this style holder you are able to drill clearance holes in the flange to accept what ever size cap screw or bolt you select. The electrode is then drilled and tapped to correspond with the mounting holes in the flange. (see figure 6-5) The use of a glue is still recommended when securing the electrode on to the flange. This electrode holder will supply through the electrode flushing if the proper holes are drilled.

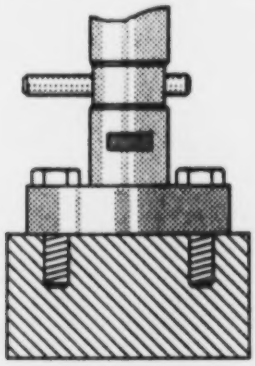


Fig. 6-5 Mounting on flanged shank

Square Holder

The square holder (see figure 6-6) is used to hold electrodes that have been machined square on one end for the purposes of mounting. It is important here that if you want to insure repeatability when using multiple electrodes that the squared end be the same size on each electrode.

Fig. 6-6 Square Holder

Holding the Shanks

All of the 3R shanks are designed to be held by a hydraulic clamping system. (see figure 6-7) This system is available for the ram of the EDM machine. It is also available for adaptation to various machine tools for electrode fabrication. The hydraulic clamp is actuated by turning a screw that is located on the side of the unit. The screw need only be turned a maximum of 2 complete revolutions.

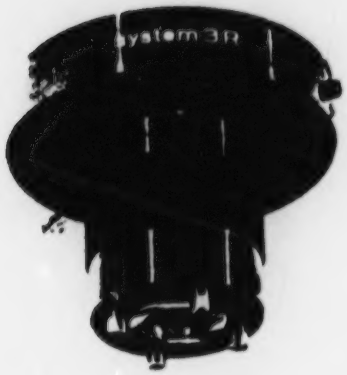


Fig. 6-7 Hydraulic Clamp for Shanks

There is a hydraulic clamp system that is used wherever you use a 5C collet system (see figure 6-8).

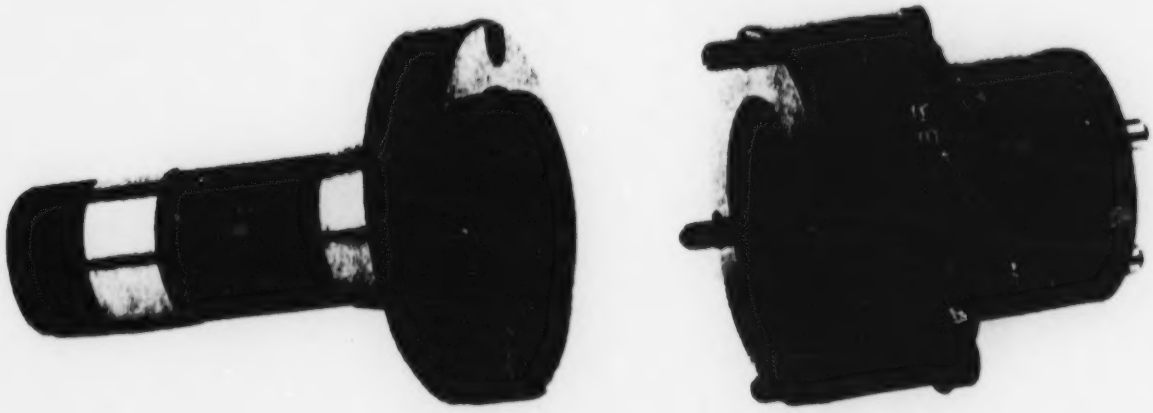


Fig. 6-8 5C Style Adapter

BEST COPY AVAILABLE

An adapter is used for the Harig Grind All that allows the same clamping system to be used even when using a spin fixture. The hydraulic chuck is mounted in place of the V-block. (see figure 6-9)

Fig. 6-9 Harig Adapter

There is also a squaring cube available that can be mounted on many different machine tools. (see figure 6-10)

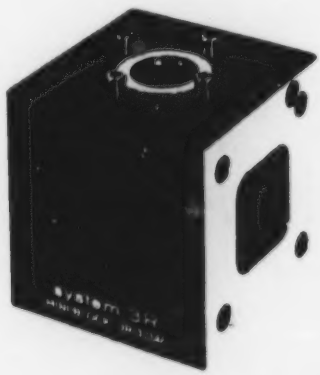


Fig. 6-10 Squaring Cube

Remembering that repeatability is very important when fabricating and using electrodes you can see how handy it is to use holders that mount the same way for machining as they do for burning. By having a common locating point you eliminate possible errors that can accumulate from making multiple set ups using multiple types of holding devices.

Calibration Of Hydraulic Clamping Systems

All of the hydraulic clamping systems (chucks) are supplied with indexing pins. These pins are used to time the detail on the electrode with the shank so that the detail is repeatable from set up to set up. Before using any of the chucks you should first check the calibration of these pins to be sure that they are in the correct alignment with the proper axis. The only way to be sure that all the chucks will repeat when indexed is to calibrate them.

Fig. 6-11 Control Rule

To calibrate the indexing pins you need to use the Control Rule. The Control Rule (see figure 6-11) is a gage that has a ground surface at 90 degrees to the pin on the shank.

The actual calibration is done by aligning the hydraulic chuck (either on a surface plate or on a machine tool). Next install the control rule securely against one of the indexing pins and clamp it into position. Now indicate the reference surface to see if it is aligned with the axis of the hydraulic clamp. If the indicator reading is other than zero you can adjust the alignment by loosening the set screw for the indexing pin and turning the indexing pin until alignment is obtained. (The indexing pins are actually cam pins.)

Other Mounting Methods

The v-block is another method for mounting electrodes that are either round or square. The v-block repeats center so it will allow repeatable positioning of round electrodes if the diameters are identical, or square electrodes if they are the same size.

These are just a few of the many methods available for electrode amounting and holding. Many shops use various methods that are adequate. The styles of holders vary from self made shanks and plates to almost anything imaginable. You do what you have to do to get the job done.

The job of the Tool and Die Maker is to select a method of mounting and holding the electrode that will be rigid enough for fabrication and offer repeatability for the degree of accuracy required for the particular job.

Notes:

UNIT 7

FLUSHING

OBJECTIVES

After completing this unit the student will be able to:

1) identify the various flushing methods used in EDM.
2) describe the purpose of flushing.
3) describe the use of the flushing control valves.

THE PURPOSE OF FLUSHING

Flushing is the most important element in the operation of an EDM machine. The best made workpieces and electrodes are of no use without proper flushing.

The purpose of flushing is to clear the gap (cutting area) of residue. If residue is left in the gap it creates the potential for electrical short circuits. This causes the electrical discharges to be transferred to the workpiece through the particles. This lowers efficiency and also creates the possibly of a DC arc.

A DC arc is when the discharges concentrate in one area due to residue in the gap. This localized discharging creates a burning effect that is characterized by a yellow colored flashing.

This DC arcing can and will create a hole in both the electrode and the workpiece if the problem is not corrected.

As you apply less peak current to the gap and strive for finer finishes flushing becomes more and more important. It also becomes more and more difficult. As the gap space is reduced with less power the space for chips to be flushed away is also reduced. Well thought out flushing will save many head aches and frustration during the operation of the EDM machine. Efficient flushing is critical for efficient burning.

TYPES OF FLUSHING

There are four basic types of flushing. They are pressure, jet, vacuum, and ram cycling. We can then take pressure and vacuum flushing and apply each two different ways depending upon whether or not the flushing pressure is applied through the workpiece or the electrode.

Pressure Flushing

Pressure flushing is when the dielectric fluid is pumped through a hole (or holes)in the electrode or the workpiece. (see figure 7-1) This type of flushing is popular and effective although there are some problems that can result from this method.

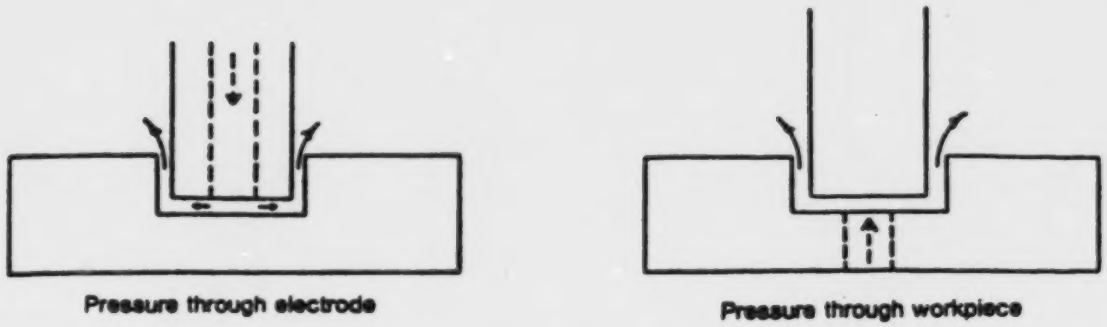


Figure 7-1 Pressure Flushing

The first problem that can arise from pressure flushing is a tapered opening in the workpiece. Pressure flushing forces the particles (residue) past previously machined surfaces. This forces particles into a position where they will allow arcing to occur between the electrode the particles and the workpiece. This arcing will result in a tapered opening in the workpiece. The more contaminated the dielectric fluid the more taper will occur. The normal amount of taper that can be expected is .0001" per 1/8" of electrode penetration.

Pressure flushing can be applied through the electrode with the flushing hose being directly connected to the electrode itself or by connecting the flushing hose to the electrode holder if the holder is plumbed for through the electrode flushing. Either method will work.

SUCTION (Vacuum) Flushing

Suction flushing (or vacuum flushing) is when the dielectric fluid is pulled through the electrode or the workpiece (see figure 7-2) via the suction hose on the flushing manifold. The vacuum method offers advantages over other flushing methods in that it eliminates the taper effect. There are no particles passing any previously machined surfaces. This prevents the arcing between the electrode the particles and the workpiece. Straight side walls are possible. It also pulls the residue out of the gap via the shortest route increasing the efficiency of the cut. Properly set up vacuum flushing is the most efficient form of flushing for the EDM machine.

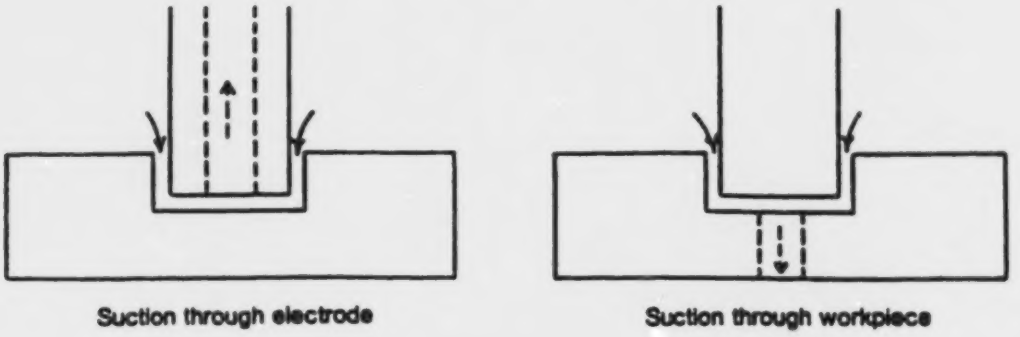


Figure 7-2 Suction Flushing

One of the problems with vacuum (suction) flushing is that the smallest pin hole will cause a loss of vacuum pressure and result in poor flushing.

Another problem with vacuum flushing through the electrode is the build up of heat. This should be watched for if this method is selected.

Jet Flushing

Jet flushing is when dielectric fluid is pumped around the outside of the electrode through a nozzle or similar device. (see figure 7-3) This method is selected when marks from flushing holes in the electrode are not allowable or when there are no holes in the workpiece to flush through.

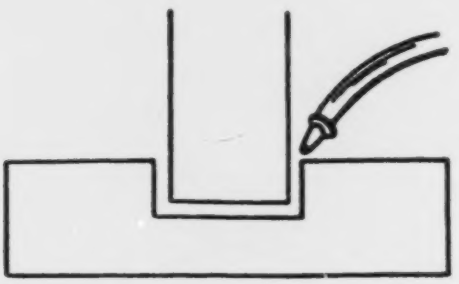


Figure 7-3 Jet Flushing

When using jet flushing you should avoid flushing the cutting area from opposite directions. (see figure 7-4) This can result in the residue being trapped in the middle of the cut and result in a loss of efficiency if not a DC arc.

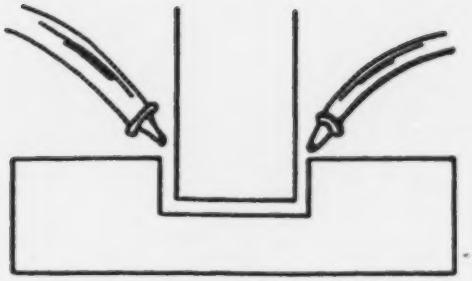


Figure 7-4 **Improper** Jet Flushing

Ram Cycling

The ram cycler can be used for improving the flushing conditions when using jet or pressure flushing. The ram is cycled up and down creating a plunger action forcing the particles out of the gap area. (see figure 7-5) The use of the ram cycler when it is not required will slow down the metal removal rate because the discharges only occur when the ram is in the down position. The up portion of the cycle does not produce any work.

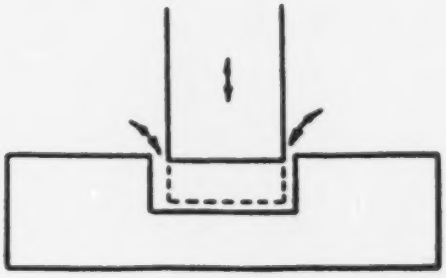


Figure 7-5 Ram Cycling

There are times when the ram cycler must be used in order to clear the gap and allow the machine to burn. It should be used only when necessary because of its adverse effect on machining time.

FLUSHING PRESSURE

The amount of flushing pressure that you should use varies depending upon the type of cut being preformed, the depth of cut and the size of the electrode being used. Use only enough pressure to effectively clear the gap area of residue. This does not mean that if a little is good a lot is better. Flushing pressure should be kept to a minimum as long as it is effective.

Excessive flushing pressure can be detrimental to the outcome of the finished product. Too much pressure can blow out the spark causing uneven wear. It can also prevent the recast of material onto the electrode and have an adverse affect on the no wear capacity of the machine. If too much pressure is applied to a thin electrode it can cause it to deflect and result in inaccuracies in the workpiece. <u>Use only enough pressure to clear the gap and burn efficiently.</u>

FLUSHING ATTACHMENTS

Flushing nozzles come in various sizes and shapes. The variety of attachments allow the operator to select one that is suited for the size and shape of each particular electrode.

A flushing pot is pictured in figure 7-6. A flushing pot is a unit that is mounted on the table of the EDM machine. It is basically a manifold. There is a flushing line connected to the side of the pot. The top of the pot may have bolt holes for strap clamps and also many holes that are drilled through to the large open area of the pot for flushing. The workpiece is placed on the pot and one of the flushing holes in the pot is lined up with a hole in the workpiece that will be used for flushing. The remainder of the holes should be plugged to avoid a loss in flushing pressure.

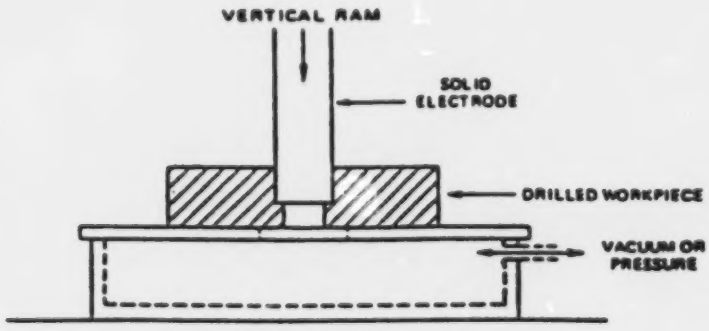


Figure 7-6 Flushing Pot

Care should be taken when using a flushing pot for vacuum flushing as a gas pocket can be created in the pot and a possible explosion could result.

FLUSHING CONTROL VALVES

There are several controls on the left side of the tank of the EDM machine. Each control has its own function and is used for a specific application.

The valve marked pressure is used to control the flow of dielectric fluid that is delivered to the line connected to the part of the flushing manifold marked pressure. This line delivers dielectric fluid when ever it is turned on, the machine controls do not have to be turned to a burning position. You do not need a ready light. The amount of pressure in the line can be read off of the gage on the front of the panel on the left side of the tank.

The valves marked AUX 1 and AUX 2 are used to deliver dielectric fluid to the hoses connected to the flushing manifold labeled AUX 1 or 2. These lines will only provide flushing when there is power to the ram of the EDM machine. (only when there is a ready light and when the machine control is set to auto, lock or orbit)

This flushing valve can also be used when the machine cycle control has been set to aux. This will provide flushing pressure only when the ram is in the up portion of the cycle. No flushing will occur when the ram is down or burning.

The valve marked suction will provide suction to the line marked suction on the flushing manifold. The amount of vacuum pressure applied is read off of the bottom gage on the front of the panel on the left side of the tank.

The valve marked bye pass is used to supply clean cool dielectric fluid to the tank while burning. This valve should be turned on when the tank is filled so that a supply of filtered dielectric fluid will be constantly entering the tank on the EDM machine.

Other controls that affect dielectric fluid flow are the hold and drain switch, and the fill button. (see figure 7-7) The hold and drain switch is used to hold dielectric fluid in the tank or to drain fluid out of the tank.

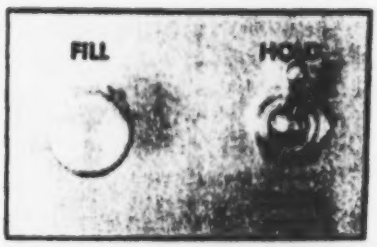


Figure 7-7 Hold and Drain Switch

The fill button will allow dielectric fluid to enter the tank. The fluid will only enter the tank when the button is held in. Releasing the button stops the flow of fluid.

Flushing is the most important element for successful EDM operation. Good flushing needs to be planned for it does not just happen. Flushing needs to be thought about even before the electrode is fabricated.

The other point that must be remembered is that the lower the peak current that is used the more difficult it is to maintain good flushing. Roughing cuts are easier to flush than finishing cuts.

Notes:

UNIT 8

THE MACHINE CONTROLS

OBJECTIVES

After completing this unit the student will be able to:

1) identify the various controls on an EDM machine
2) describe the function of each control

INTRODUCTION

There are many controls on the panel of the EDM machine. Each control has a specific function as related to the set up of the machine or the adjustment of the cut. Some of these controls are set according to charts and others are used when fine tuning or adjusting the stability of the cut. The following is a list of the controls found on the power supply and on the machine control panel that is attached to the machine tool. These particular controls are found on the Hansvedt H-Pulse 502. Note the location of each control on the illustrations.

POWER SUPPLY CONTROLS:

The power supply controls are located on the power supply unit that stands alone along side of the EDM machine tool. (see figure 8-1) The power supply contains controls that are used to set predetermined parameters. It also contains controls that may be used to stabilize the cut.

Figure 8-1 Power Supply Control

1. **Efficiency Meter**: This meter tell you how efficient your cut is. Indicates how many of the pulses actually make contact with the workpiece. The range of the meter is from 0 to 100 %. Use this meter to help you adjust the servo speed and gap adjust knobs.

2. **Amp Meter**: This meter is a dual range meter (note the high and low scale) that indicates the average amperage that is being used in the gap. The range of the meter is from 0 to 50 amps. It does not indicate the peak amperage that is set.

3. **% On-Time Meter**: This is the percentage of the time that the pulse is on (or off). The range of the meter is 0 to 100% (although the maximum on-time allowable is 80%). This meter has a direct affect on the average amperage being used at the gap.

4. **Gap Initiation Control**: Use this control to set the striking voltage that ionizes the dielectric oil. The striking voltage determines how close the electrode is to the workpiece at the time the amperage begins to flow. The choices are 75, 150, or 300. 75 volts is used for fine finishes and allows the electrode to be at its closest to the work piece. 150 and 300 volts can be used to stabilize the cut and improve flushing.

5. **Lead Selector**: The H-Pulse 502 is a 50 amp (average amps) power supply that has two leads of 32 peak amps each. When both leads are attached to the head od the machine you select one lead for 32 peak amps or two leads for 64 peak amps.

(32 peak amps are approximately equal to 25 average amps.)

6. **Peak Current Control**: This control allows you to select the peak current. Peak current is chosen from a chart depending on the surface area of the electrode. The selection on the control are 1/32, 1/16, 1/8, 1/4, 1/2, 3/4, or full. Each of these represents what portion of the available peak current you are using. (i.e. 1/2 of one lead would equal 16 peak amps.)

7. **% On-Time Knob**: This knob is used to set the calculated % on-time from the cutting parameter charts. The set % on-time is then read off the % on-time meter.

8. **Electrode Protection Switch**: The selections on this switch are Graphite, Metallic 1, and Metallic 2. Graphite offers the most protection at the gap against DC arc. Metallic 1 offers the next best level of protection, and Metallic 2 offers the least amount of protection. The switch actually monitors for a specific voltage in the gap and the smaller the voltage the smaller the gap, and the less protection against DC arc.

9. **Polarity Switch**: This switch allows you to set the polarity of the electrode. With the switch on POS the ram is charged (+), with the switch on Neg. the ram is charged (-).

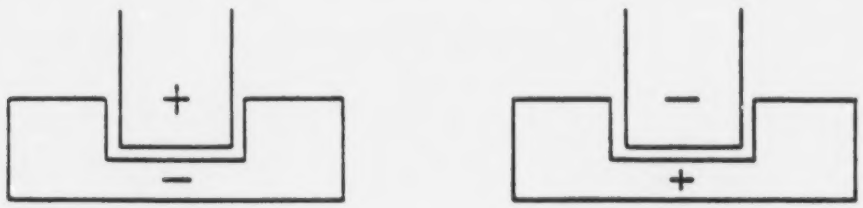


Figure 8-2

10. **Follower**: This switch is used when you hook two power supplies up in series.

11. **Emergency Stop Switch**: This switch shuts off all power to the machine tool.

12. **Arc Duration/Multiplier**: The product of the arc duration times the multiplier will allow you to set the required arc duration. (i.e required arc duration - 50, set arc duration knob = 37, set multiplier = 1.6, 32 X 1.6 = 48. You would use this combination if you wanted to set an arc duration of 50. This is as close to the actual value as possible.)

13. **Gap Power LED**: This lights up to indicate when there is power to the ram.

14. **Capacitor Mode**: These switches are used to include capacitors in the cutting circuitry. They are normally used to machine carbide and their purpose is to stabilize the cut.

MONITOR AREA OF POWER SUPPLY:

1. **Reset**: Use this button to reset the alarm. (turn the alarm off)

2. **Voltage LED**: A protection device that monitors the line voltage. Should the line voltage increase above the allowable level the LED will light up, the alarm will sound and the power to the gap will be shut off. If this occurs you should attempt to operate the machine again. A second alarm indicates that the incoming line voltage should be checked by an electrician.

3. **Amperage LED**: A protection device that monitors the amperage at the gap. If you would draw more than the 50 average amp capacity of the machine it will shut off the gap power, illuminate up the LED and sound the alarm. If this happens

you should turn down the % on-time or adjust the gap adjust switch to open the gap and attempt operation again.

4. **Filter LED**: This device monitors the air flow in the power supply cabinet. It will sound when the machine is powered up and will shut off if sufficient air flow is entering the cabinet. If the alarm continues to sound and the LED is on then the filter on the back of the power supply should be replaced.

5. **Gap LED**: This is a gap fault monitor. It monitors the cutting condition in the gap. When an improper condition exists in the gap area the light will come on. If the condition does not correct itself the light will stay on and the alarm will sound. When this happens you can try to continue the cut, if this results in the gap fault re-occurring then you will have to raise the head and clean the surface of the workpiece and the electrode. This device is designed to help protect against DC arcs.

MACHINE CONTROL PANEL

The machine control panel is the panel that is suspended over the machine tool work tank. (see figure 8-2) The machine control

panel contains controls that are used to turn the machine tool on and off, supply power to the gap, and to stabilize the cut.

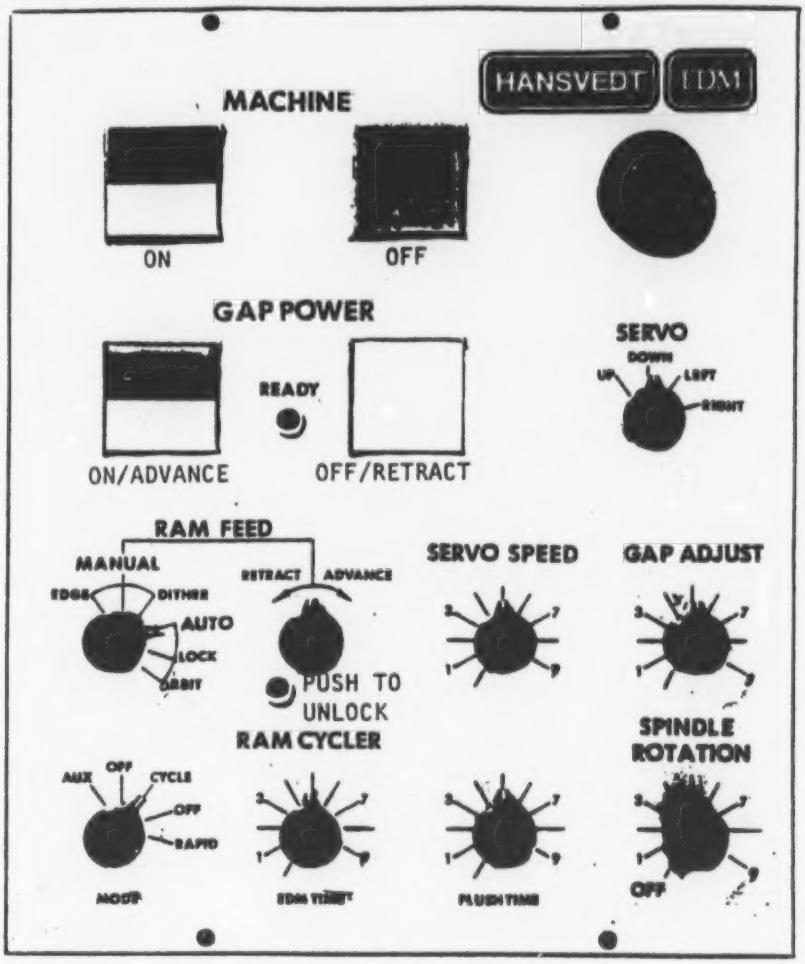


Figure 8-2 Machine Control Panel

1. <u>On</u>: Turns on the machine tool.

2. <u>Off</u>: Shuts off the machine tool.

3. **Gap Power On/Advance**: When the ready light is on and the mode switch is in either auto, lock or orbit this button turns on the cutting power. Hold in this button for rapid advance of the ram. (Be careful not to smash your electrode into the workpiece.)

4. **Gap Power Off/Retract**: Turns of the cutting power. Hold this button in for rapid retraction of the ram.

5. **RAM FEED/UNLOCK**: Used in positioning mode to move ram up or down. When hydraulic lock LED is on the ram is locked and the knob must be pushed in and rotated to move ram up or down.

6. **Manual Positions:**

Edge: Use this position when your want to pick up the edge of your workpiece with your electrode. When you use the machine table handles to move the workpiece into the edge of your electrode a beep will occur when contact is made.

Manual: When the control is in this position you can advance and retract the ram by depressing the RAM FEED/LOCK knob and turning it to the direction you want the ram to move.

Dither: This position is used for picking up the surface of the workpiece with the bottom of the electrode. With the control placed in this position use the advance/retract knob (no need to depress the knob when in dither) to touch the electrode off on the top of the workpiece. You would now set the depth of cut with either the micrometer stop or the D.R.O..

7. **AUTO POSITIONS**:

Auto: The ram will return to its top position when the gap power is turned off. The gap power may be turned off because the ram reached the set depth, or because of an alarm, or because the operator stopped the cut for another reason.

Lock: The ram will maintain its position when the gap power is turned off. The gap power may be turned off because the ram reached the set depth, or because of an alarm, or because the operator stopped the cut for another reason.

Orbit: This position is used when you are also using an orbiting attachment. It allows the machine to stay at the required depth and maintain gap power while the orbiting device sparks out (finishes the cut).

8. **RAM CYCLER CONTROLS**:

The ram cycler controls allow the ram to cycle up and down (in and out of the cut) for improved flushing conditions. This is very helpful when you can not use pressure flushing.

Aux: Along with using the auxiliary flushing control valves provides for flushing when the ram is in the up position only. There is not flushing delivered during the down or cutting portion of the cycle. This uses the same cycle speed as the cycle mode.

Off: Turns off the ram cycler.

Cycle: Turns on the ram cycler allowing the ram to cycle in and out of the cut to improve flushing. The cutting time and flushing time are set with the control knobs marked EDM time flush time.

Rapid: Turns on the ram cycler but operates the cycler at 10 times the normal cycle speed.

9. **Servo Speed**: The servo speed controls the ram travel speed and also the sensitivity response of the ram. This control is used to stabilize the cut. It should be set so that there is a slight

bounce on the trav-a-dial needle, too high of a setting will produce a groan from the machine. Avoid setting the servo too high or too low. A setting of 6 to 7 will provide for maximum ram response.

10. **Gap Adjust**: The gap adjust controls the distance between the electrode and the workpiece. This switch is used to stabilize the cut. If set too high the ram will travel up instead of down.

11. **Ready Light**: To obtain a ready light you must have the float in the tank covered by the proper amount of fluid, the fluid pump must be on, the top door must be in place on the tank, the micrometer stop must not be resting on the micro switch, and the digital read out can not be on zero or have a positive number displayed.

SET CONTROLS:

The following controls are to be set and left alone during operation of the EDM machine when a specific over cut, finish, or wear factor is to be held constant. These controls are not for stabilizing the cut. They are parameters that must be set before the machining operation takes place. These have a direct affect on either overcut, surface finish, or wear.

The controls are: **Peak Current, and Arc Duration**

STABILIZING CONTROLS:

The following controls are the controls are used for stabilizing the cut during the EDM process. They do not change the surface finish, the amount of overcut, or the amount of wear.

Gap Initiation Control, Electrode Protection Switch, Servo Speed, Gap Adjust, and the Ram Cycler.

The % on-time control is slightly different in that we may turn down the % on-time to stabilize the cut, but if we do not want to cause unusually high wear we should not turn the % on-time to a value that is higher than the value calculated from the chart. Turning the on-time to a value higher than that from the chart would effectively over power the electrode. Over powering the electrode is placing more average amperage into the electrode than the surface area will allow it handle efficiently.

Notes:

UNIT 9

PLANNING A CUT

OBJECTIVES

After completing this unit the student will be able to:

1) correctly size electrodes.
2) select the correct % on-time for a given electrode.
3) select the correct peak current value for a given electrode.
4) select the correct arc duration for a given peak current and wear allowance.

INTRODUCTION

After you have determined that the best way to do a job is with EDM, you select an electrode material. After you select the electrode material you then begin the process of calculating the size of the electrode(s), and determining the power settings for the EDM machine. Electrode sizing and power settings are covered together because they are directly related. Their relationship will become more clear as this unit goes on.

HOW OVERCUT AFFECTS ELECTRODE SIZE

Overcut is the difference in size between the electrode and the amount of material removed by the electrode during the EDM process.

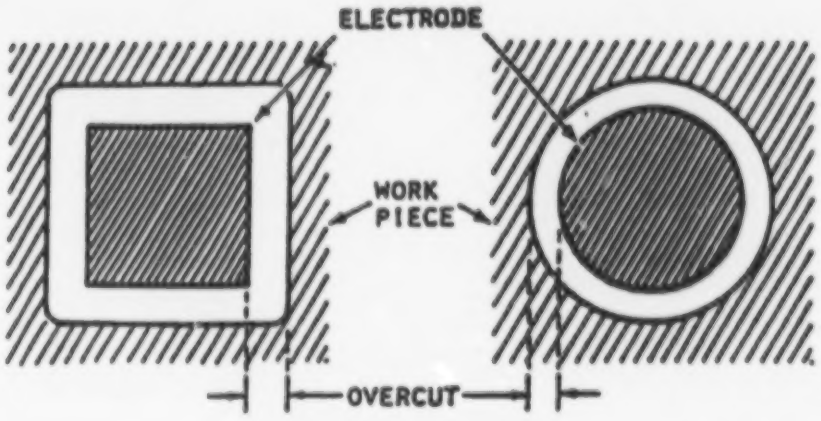
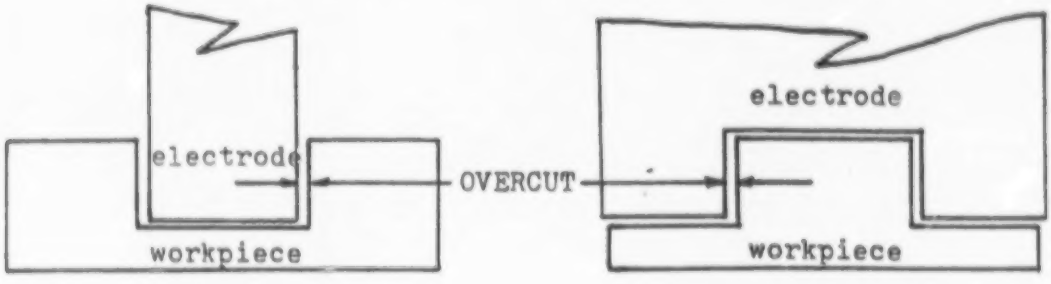


Figure 9-1 Overcut

In other words the difference between the size of the electrode and the pocket it produces (see figure 9-1). The amount of overcut varies depending upon the electrode material, the workpiece material, and the power settings. Overcut is always stated in terms of thousandths per side. The following illustrations show how overcut affects the size of electrodes. (see figure 9-2)



Electrode smaller than detail

Electrode larger than detail

Figure 9-2

Notice that the electrode is made smaller when producing an opening, but is made larger when producing details like standing ribs or other similar features.

Overcut does not affect **the size of the electrode** in the axis of travel. That means that if the machine cuts in the Z axis the overcut only affects the dimensions in the X and Y axes. All Z dimensions (or steps) on the electrode are the same as the dimensions (or steps) on the detail.

Next three examples of calculating overcut and machining parameters will be presented. The examples are all different and are representative of the various conditions that have to be considered when determining overcut and cutting parameters.

SIZING THE ELECTRODE

Determining the size of the electrode is a process that looks more complicated than it actually is. To begin the calculation you must first gather information related to the cut to be performed. The information that you will need to look at concerns the detail you are trying to obtain, the surface finish required and the area of the cut.

Example #1

For this example we want to use only one electrode. The production of this pocket will not require that sharp corners be held. It will however require a bottom as flat as possible with one electrode, so a setting that will provide 1% wear will be necessary. The pocket requires a surface finish of 300 micro inches or less.

The first step is to determine the area of the detail that you are going to EDM. This is done by multiplying the length times the width. For a simple shape this is pretty straight forward. (see figure 9-3) This is a rectangular pocket of uniform depth. The area is (.500" X .500") = .25 sq.in..

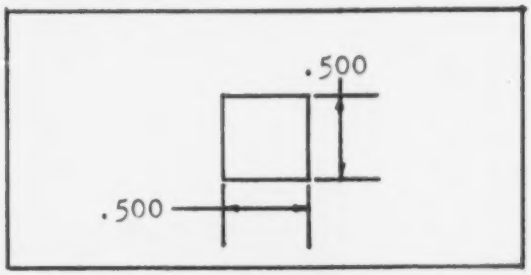


Figure 9-3
Example #1 .500 sq.in. pocket

Now with this information we go to one of the graphs that is specifically labeled for the type of electrode material and workpiece material that we are using. In this example we will use a graphite electrode and a steel workpiece. We will use graphite positive / steel negative for a low wear or no wear application

The graphite positive indicates that the ram of the EDM (where the electrode is mounted) has a positive charge.

Now look at graph C-E graphite (+) /steel (-). (see figure 9-4) This is the cutting speed chart and we will use it to determine the peak current setting and the % on-time. It can also provide you with the average amperage and material removal rates for your particular application.

First you look in the column labeled cut area and you look up the column until you locate the number of square inches that you will be using in your electrode (in this case .25 sq.in.). You now draw an imaginary line across the page and see where it crosses the various peak current settings. (If all you were looking for was speed you would choose the highest power setting available.)

Since our machine has 2 leads you do not need to look at the F:6L or the F:4L. (These stand for full power 6 leads and full power 4 leads respectively.) The highest power setting available to use the full power 2 leads. Now take the intersection point of where the .25 sq. in. line crossed the F:2L and follow it straight down to the bottom of the graph. The on-time for this setting is approximately 8%. Reading the % on-time for the remaining settings you should come up with. (see figure 9-4)

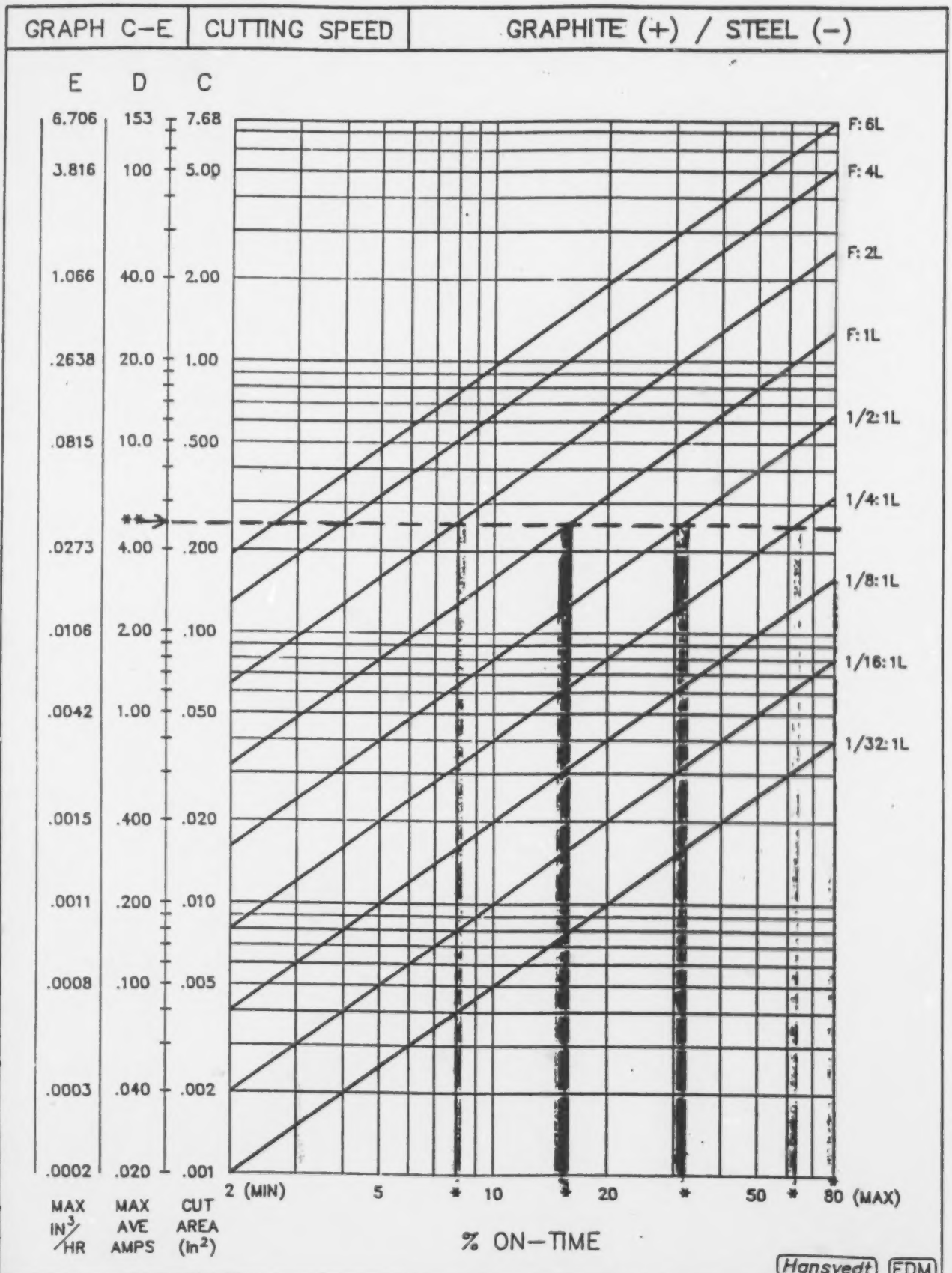


Figure 9-1

BEST COPY AVAILABLE

F:1L = 17%

1/2:1L = 32%

1/4:1L = 64%

1/8:1L = 80%

1/16:1L = 80%

1/32:1L = 80%

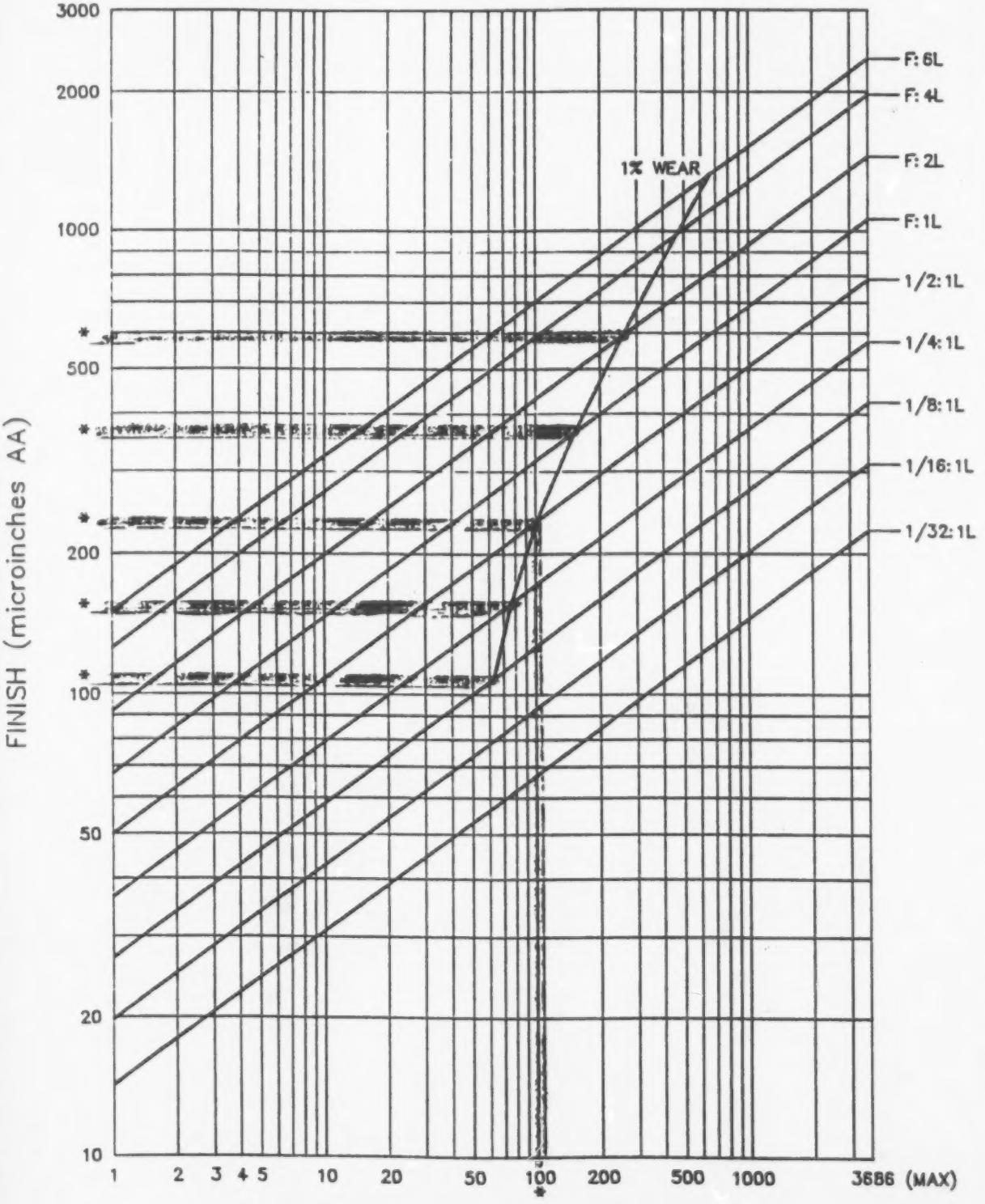
You will notice that whenever the power setting lines intersect (the imaginary line from the electrode area) off of the chart to the right that the % on-time is 80%. 80% is the highest allowable on-time for the EDM machine.

Using these steps and some practice you will soon be able to determine the % on-time for any electrode workpiece combination.

The size of the electrode allows a selection of any power setting available on the machine, but any power setting will not give the required surface finish. So to determine which power setting needed to produce the required surface finish another graph must be consulted.

The graph that will provide surface finish information is labeled graph B finish graphite(+) / steel(-). (see figure 9-5) Now locate the 1% wear line. Look at the surface finishes that appear from top to bottom along the left side of the graph.

GRAPH B	FINISH	GRAPHITE (+) / STEEL (−)



Hansvedt EDM

Draw an imaginary line from the intersection point of the 1% wear line and the peak current line straight across to the surface finishes on the left side of the graph. You can now determine the finish that is obtainable for each power setting. They are as follows:

F:2L = 600 micro inch

F:1L = 375 micro inch

1/2:1L = 240 micro inch

1/4:1L = 170 micro inch

1/8:1L = 110 micro inch

Notice that the graph does not list any 1% wear setting for the 1/16 or the 1/32 settings. This is because that these lower power settings 1% wear is difficult to obtain.

Now go back to the desired finish for the pocket. You would choose the 1/2:1L setting because that would be the highest power setting that will provide for a 300 micro inch finish or better. Using the lower setting would improve the finish but would also slow down the cut. A finer finish is not required so there is no good reason to make the cut slower.

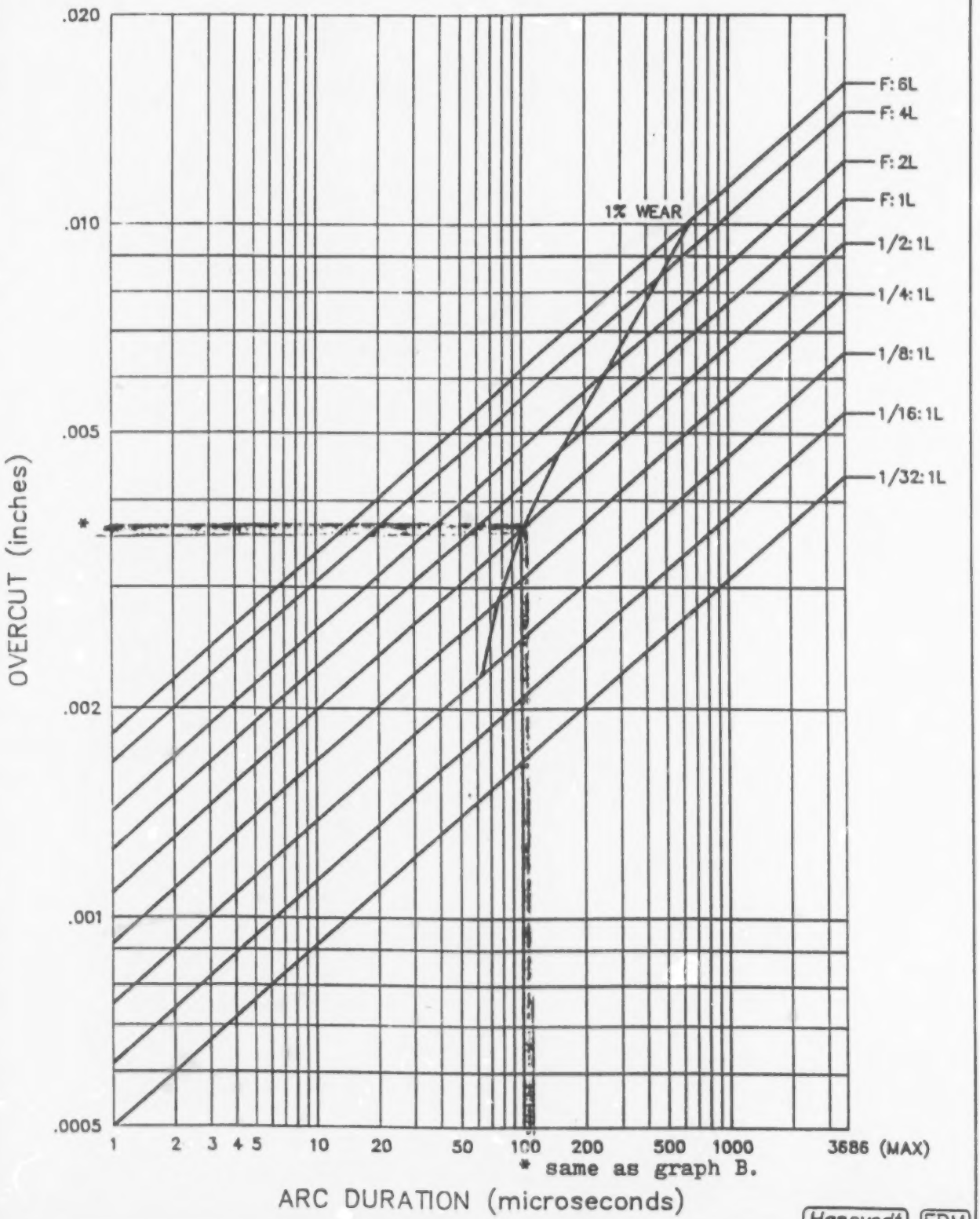
This chart can also be used to determine the arc duration setting for the power supply. This is done by looking a the intersecting

point of the 1% wear and the required power setting. (in this case 1/2:1L) Follow that intersection straight down to the bottom of the chart and read the corresponding arc duration. It should be 100 microseconds. (see figure 9-5) Remember that there is only one arc duration that will yield 1% wear for each power setting.

Now a calculation can be made for the amount of overcut that can be expected for this particular electrode at the settings that have been already determined. Look at graph A labeled Overcut graphite(+) / Steel(-). (see figure 9-6) Look for the intersection of the 1% wear line and the 1/2:1L peak current setting. Draw a straight line over to the left from that intersection to determine the overcut for that setting. It should be .0038" per side. To determine the electrode size you need to subtract the calculated amount of overcut from the electrode. The total over cut is .0076". (.0038" X 2) Subtracting .0076" from .500" you get .4924". The electrode should then be 4924 X .4924.

Remember that overcut is always given per side. The overcut amount is measured at the peaks of the finish. This should be kept in mind if the job is going to require polishing, or if you are using multiple electrodes for a job.

GRAPH A	OVERCUT	GRAPHITE (+) / STEEL (−)



In summary example #1 was a .5" X .5" pocket requiring a 300 micro inch finish or better at 1% wear. The following settings and calculations were determined:

Peak current setting : 1/2:1L
% on-time : 32%
arc duration : 100 microseconds
overcut : .0038"/side

These are the steps that should be followed to obtain the cutting parameters for setting the power supply on the EDM machine and for calculating the overcut for sizing the electrode. These are the steps that are followed for a job that only requires one electrode for the desired detail.

Example #2 A Multiple Electrode Job

Some pockets require multiple electrodes be cause of the surface finish requirements or fine detail to be held in relationship to their area. Now an example of this will be covered in detail.

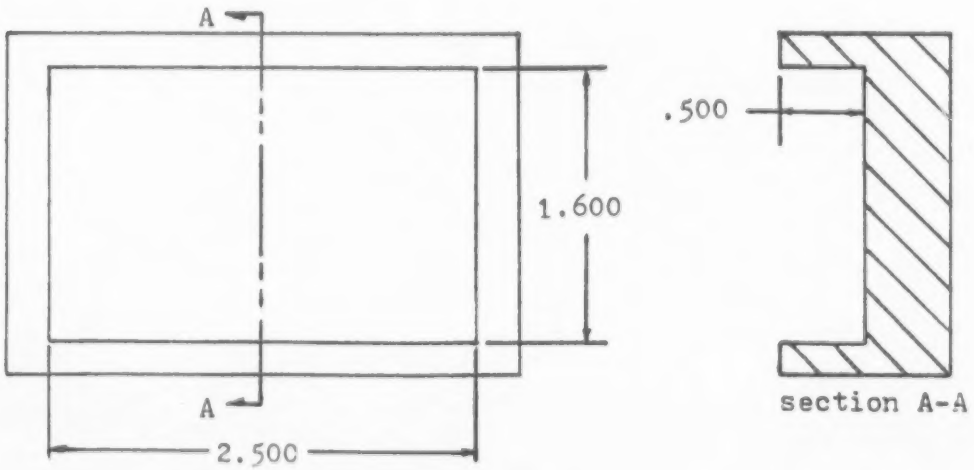


Figure 9-7
Example #2 A 2.500 X 1.600 X .500 pocket

The pocket in figure 9-7 has an area of 4 sq.in., and requires a minimum surface finish of 200 micro inches. It will be taken to a depth of .500" for a total of 2 cu. in. of material removed. So all other requirements are known the material and polarity is as follows: electrode-graphite (+) and the workpiece-steel (-), 1% wear. Now the graphs can be examined to determine the cutting parameters and the amount of overcut.

This time start out by looking at graph B Finish for graphite(+)/steel(-). (see figure 9-8) In order to obtain a minimum 200 micro inch finish the machine would have to be set at 1/4:1L with an arc duration of 75 micro seconds.

Now look at the graph C-E labeled cutting speed for the same electrode material/workpiece combination. (see figure 9-9) Find 4 sq. in. in the column labeled cut area and follow it across until it intersects the line for 1/4:1L. It intersects off of the graph on the right side therefore you use 80% on-time as discussed previously. The material removal rate for this peak current setting / % on-time combination is approx. .054 cu. in./hr. (slow) Looking back we find that there is a total of 2 cu. in. of material to remove. At the calculated peak current setting for the desired surface finish this would take 37 hrs. from start to finish. (if everything goes well) This would not be very practical at the going rate for EDM machining.

GRAPH B	FINISH	GRAPHITE (+) / STEEL (−)

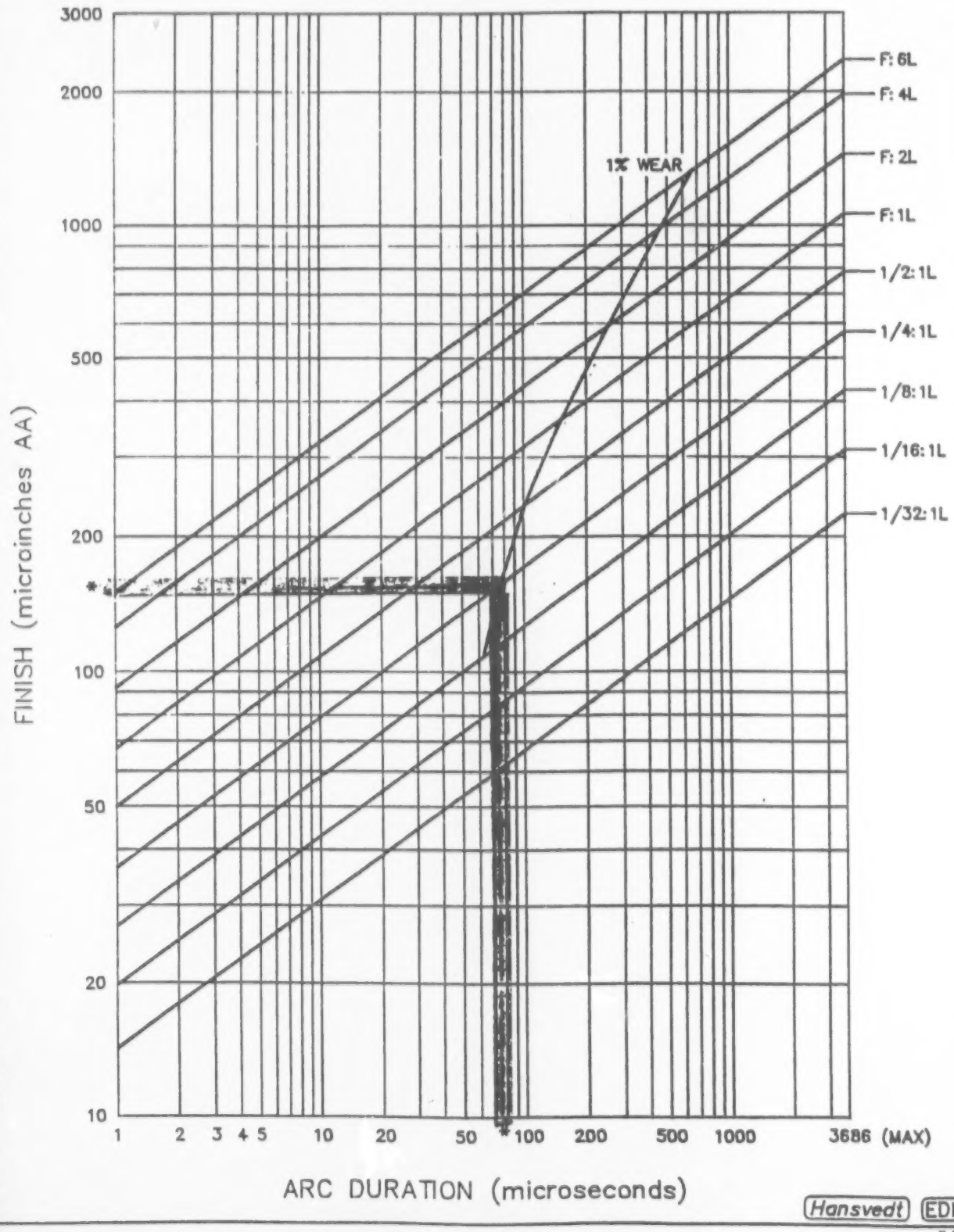
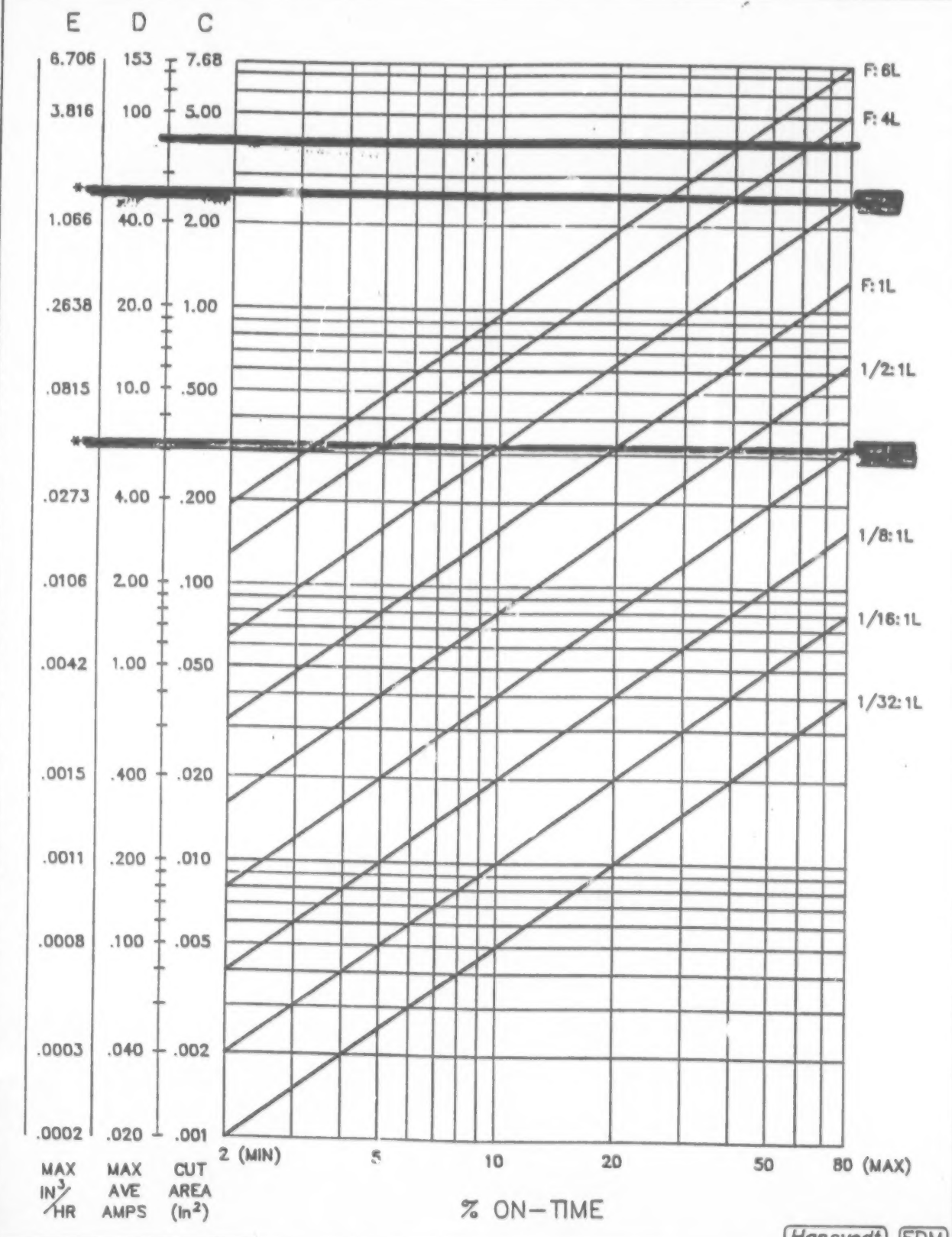


Figure 9-8

GRAPH C–E	CUTTING SPEED	GRAPHITE (+) / STEEL (–)



Hansvedt EDM

7/89

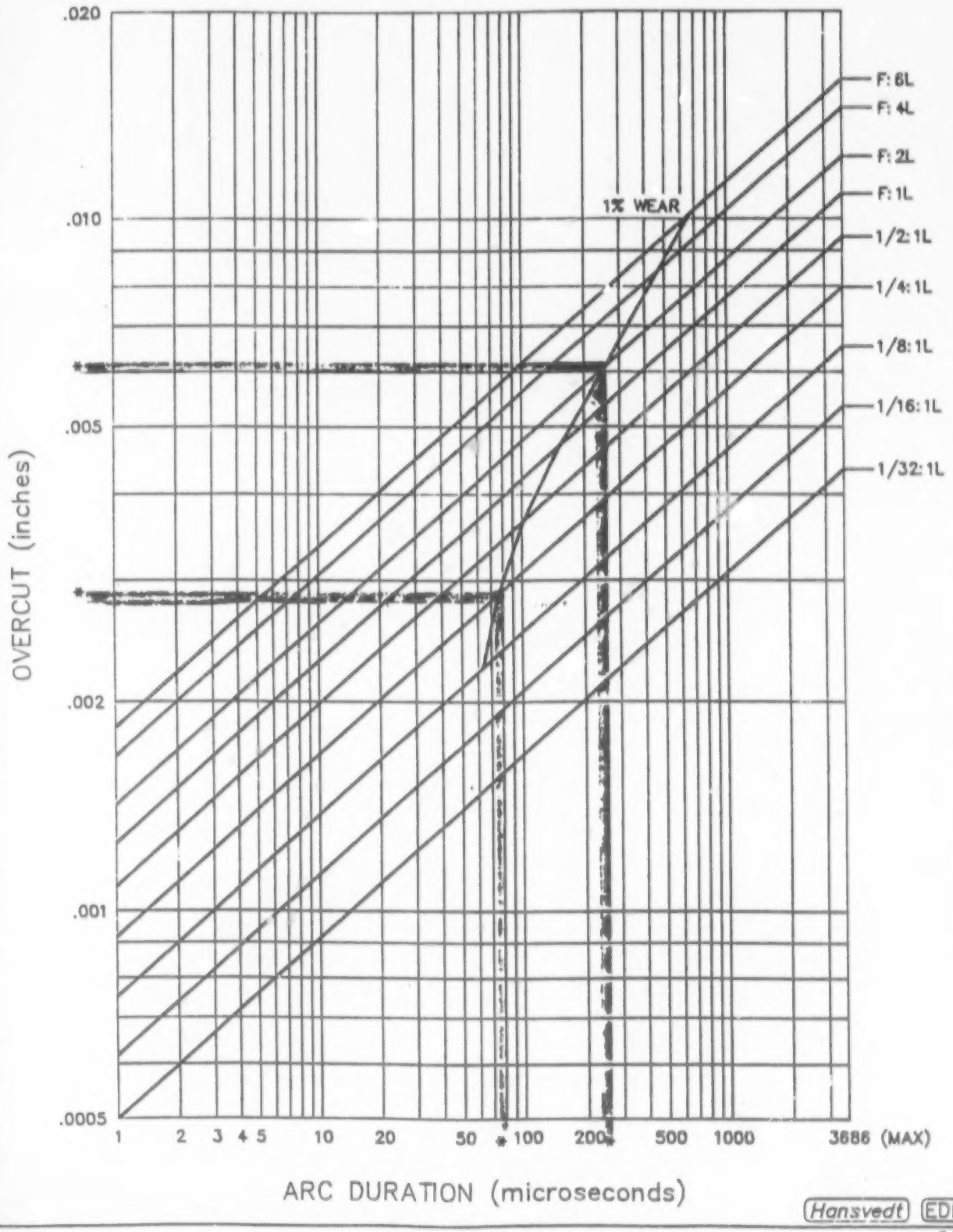
The solution for this problem is to use more than one electrode. Use a roughing electrode to remove the majority of the stock and the use one or more electrodes to obtain the desired finish and detail.

Again using the cutting speed chart (see figure 9-9) a 4 sq.in. electrode can use a peak current setting of F:2L with an 80% on-time. This has a metal removal rate of approx. 2.4"/hr. (quite an improvement over .054"/hr.) This would make roughing time approximately 50 minutes. Since this the first electrode for this pocket the information from the graphs should be written down and labeled "rougher".

To calculate the overcut and arc duration for the rougher consult the graph A labeled overcut graphite (+) / steel (-). (see figure 9-10) The overcut for an electrode using F:2L and 1% wear is .0062" per side and the arc duration is 260 microseconds. Looking at the surface finish graph you will find that the surface finish for this setting will be 600 micro inches. This is not acceptable for the finished pocket. (but this is only the roughing electrode) The finish will be improved with a finishing electrode.

Now calculations can be made for the finishing electrode. Sizing the electrodes will be covered later. We have already determined

GRAPH A	OVERCUT	GRAPHITE (+) / STEEL (−)



what the peak current setting and % on-time should be for the required surface finish so we will use that for our finishing electrode calculations. The peak current was determined to be 1/4:1L and on-time of 80 %. Now look at the graphs to determine the overcut, and arc duration. (see figure 9-10) The overcut for 1/4:1L at 1% wear is .0029"/side and the arc duration is 65 micro seconds.

Summary:

Rougher = F:2L peak current setting
80% on-time
.0062" per side overcut
260 microsecond arc duration

Finisher= 1/8:1L peak current setting
80% on-time
.0029" per side overcut
75 micro second arc duration

The sizing of multiple electrodes varies slightly form the sizing method used for a single electrode job. The finisher is sized the same way a single electrode job, but the rougher is sized by subtracting the overcut from the size of the finished pocket and then subtracting an extra amount of material so that there is stock left for the finisher to burn. This extra amount of material may

vary from shop to shop but for our purposes we will take an additional:

.006" per side - F:2L
.006" per side - F:1L
.003" per side - 1/2:1L thru 1/8:1L

So the size of the rougher for this example would be:

2.0000"
- .0134" (.0062" over cut per side X 2)
1.9866"
- .012 " (.006 safety per side X 2)
1.9746"

Roughing electrode size = 1.9746" X 1.9746"

The size of the finisher would be:

2.0000"
- .0058" (.0029" over cut per side X 2)
1.9942"

Finishing electrode size = 1.9942" X 1.9942"

Example #3 A Stepped Electrode

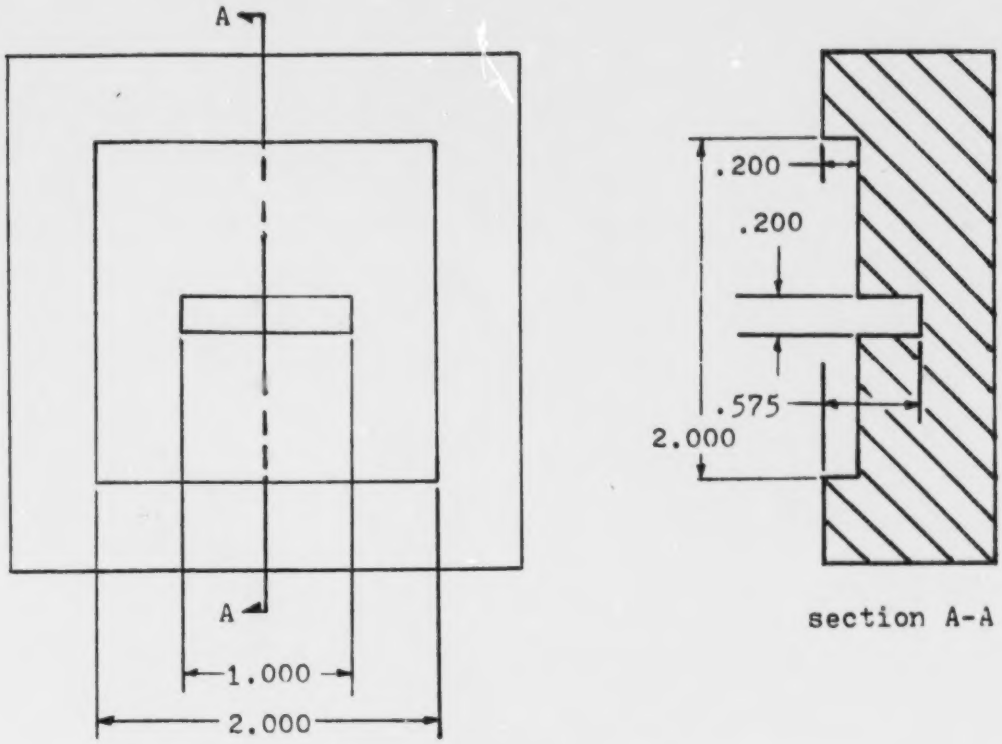


Figure 9-11
Example #3 A stepped pocket

This example pocket is quite different from the first or second example. (ee figure 9-11) Note that the pocket depth is not uniform over the entire area. (different areas have different depths) This will have a definite affect on the settings for the EDM machine. This will be discussed later as we go through the calculations.

The bottom of the pocket is 1" X .2" and is .375 deep. The top of the pocket is 2" X 2" and is .200" deep. Whenever you have a

pocket with a step in it you should not take the large size for all your calculations just as you should not take the small size for all of your calculations. You need to take a combination of the two.

First do the area calculations for both steps:

1" X .2" = .200 sq.in. 2" X 2" = 4 sq.in.

The electrode material is graphite(+) and the workpiece is steel (-). Now look at graph C-E (figure 9-12). First look at the peak current setting and % on-time for the large area of 4 sq. in.. (Remember that our machine has 2 leads) Notice that the 4.0 sq. in. would intersect the F:2L power setting line off of the graph at the right. This means that you can use an on-time of 80%. Now look at the peak current setting for the .2 sq. in. area. Follow the .2 line across until it crosses that same F:2L line that we looked at for the 4 sq.in. area. You see that the % on-time for the small end is 6%. If the machine were set for the large area the % on-time would be too high for the small area and it would result in destroying the electrode. What actually happens here is that with the same peak current but different % on-time the average current is affected. The 80% on-time will result in an average amperage of 50 amps. The 6% on-time represents an average amperage of 4 amps (a large difference). The small area would not hold up to the higher average amperage. (Refer to the average amperage on the graph)

When this type of situation arises you can apply this general rule: calculate the surface finish, overcut, and arc duration for the large area. Then calculate the % on-time for both areas and change that setting when the correct depth is reached. (As with all other general rules this rule to will have exceptions and will not apply all the time.)

Example: peak current setting F:2L

6% on-time for the first .375 step

80% on-time for the last .100 step

It is important to remember that 1 sq. in. of graphite will only handle 20 average amps. of current. Over powering an electrode will result in excessive wear possibly to the point of destroying the electrode.

The surface finish requirements and the sharpness of detail required for example #3 would help determine how many electrodes would be required to complete this job. The same guidelines can be followed as discussed earlier regarding single or multiple electrode calculations.

Graphs for different electrode combinations are in the appendix of this manual for reference. They will provide all the information necessary to calculate overcut and machining parameters.

Notes:

UNIT 10

SETUP and OPERATION

OBJECTIVES

After completing this unit the student will be able to:

1) setup the workpiece in the EDM machine.
2) locate the electrode in reference to the workpiece.
3) start and stabilize an EDM cut.

INTRODUCTION

The information up to this point has covered the terms, the concepts, the theory, and tooling for EDM. This unit will show how to setup the EDM machine, start a cut, and stabilize that cut. The information will help you accomplish these tasks but in order to become proficient at EDM setup and operation you will need to perform EDM machining.

START UP

The machine tool start up is not a complicated one. The tool is turned on by pushing the MACHINE ON button located on the machine control box. If the machine does not power up check to be sure that the EMERGENCY STOP button is released.

UNIT 10

WORKPIECE SETUP

In order to setup the workpiece some information will be needed. What type of flushing is going to be used? How is the electrode going to be referenced to the workpiece? (in all three axes) This information will help determine where and how the workpiece is going to be clamped.

Whenever the workpiece is going to be indicated or referenced with an electrode it should be free of all dielectric fluid, burrs, and any other foreign substance that will cause inaccurate readings. This is especially true for electrode pick up on the workpiece. The dielectric fluid is an insulator by design and will insulate between the electrode and the workpiece. This insulating barrier can cause inaccuracies when using the machines electronic sensors for edge and top pick ups.

Once the workpiece has been clamped to the table (or flushing tank) it should be indicated straight with the axis of the machine table. This can be done by either using a magnetic base and indicator or by using the indicator holder that fits into the hydraulic clamping system on the ram of the EDM machine. The movement of the ram is controlled by the RAM FEED switch on the machine control box. (refer to unit 8 for more information)

Setting the X and Y Axis

After the workpiece has been indicated straight it can be referenced to the electrode by a couple different methods. With the 3R tooling it is convenient to swing indicate the workpiece. Since all the holders have a common shank using the center of the shank as a reference point is a very accurate method. There is a holder designed for swing indicating that holds the indicator and fits into the hydraulic clamp on the ram of the EDM.

It is also possible to use the electrode to find the edge of the workpiece. To do this set the RAM FEED switch on the machine control box to EDGE. This turns on a sensor that will emit an audible sound when the electrode comes into contact with the workpiece.

Which ever method is used for establishing the X and Y zero of the workpiece be sure to set the digital read out or the machine table dials to zero when you are done.

Setting the Z Axis

Now that the X and Y axes reference has been established all that is left to establish the Z axis reference. The Z axis controls the depth of cut. The Z reference is set by picking up the top of the workpiece with the electrode. To do this the RAM FEED switch must be set to DITHER. The ram travel is now controlled by the

RAM FEED knob. The ram will feed up or down in Z by turning the knob to either advance or retract. The speed of travel by the degree of rotation of the knob. The pickup of the surface is done by electronic sensors. Even though sensors are used for this type of pick up do not allow the electrode to hit the top of the workpiece with a lot of force.

With the electrode resting on top of the workpiece the Z reference should be set. This can be done in one of two methods, with either the micrometer stop on the right side of the Ram Head or with the Digital Read Out. (D.R.O.)

The D.R.O. can be used for the Z axis reference. It is used to establish the depth of cut. (indirectly the Z zero point) To set the D.R.O. for any job you enter the depth of cut into the Z register as a negative number. (This must be done while in dither and with the electrode in contact with the workpiece.) When the D.R.O. reaches Zero it will shut off the gap power.

The micrometer stop is used to set the top of the workpiece as zero. While the electrode is touching the top of the workpiece (the machine control knob is still in dither) you set the micrometer stop so that it contacts its' shut off switch. The switch contact should correspond with the electrode being in

micrometer stop so that it contacts its' shut off switch. The switch contact should correspond with the electrode being in

contact with the top of the workpiece. The depth of cut can be set on the micrometer after the electrode has been retracted from the workpiece. (see note below)

NOTE:

No matter which method you use to set the Z reference is recommended to also set the Trav-a-dial to zero also. This is a good safety reference and it can be very useful.

Be sure to retract the ram from the top of the workpiece when you are finished setting the Z reference.

Z Depth Calculation

The depth of cut for each electrode can be calculated by subtracting the overcut value for that electrode from the depth of the detail on the print. (e.g. The required depth is .500 and the overcut is .007". The depth set on the EDM is .493".) This will normally leave stock at the bottom of the pocket as the gap distance is smaller than the overcut. This is a safe starting point.

POWER SUPPLY and MACHINE CONTROL SETUP

Power Supply Controls

The power supply controls that must be set are the % on-time, arc duration, peak current, number of leads, gap initiation, polarity, and the electrode selector. (Refer to UNIT 8 for more information.) These controls for the most part are set and left alone. The exceptions to this are the gap initiation switch, and the electrode selector switch. These two switches can be used to help stabilize the cut.

The % on-time switch is also an exception to the set and forget rule. The % on-time should be set lower than the graph calls for at the beginning of each cut. This is done to protect the electrode from initial excessive wear. Once surface area contact has been increased then the % on-time can be brought up to the value that was calculated form the graph. **IT SHOULD NOT BE SET HIGHER THAN THE CALCULATED VALUE.** If a higher % on-time is used than was calculated for the area of the electrode, over powering will result. Overpowering causes excessive wear.

Machine Controls

To begin a cut the following machine controls need to be set. The RAM FEED selector must be set to a cutting position, either AUTO or LOCK. (Refer to UNIT 8 for more information.) The SERVO switch is set in the down position. The SERVO SPEED knob is set to about 7. (this is a good place to start) The GAP ADJUST knob is set

just under 1. (again this is a starting position) The RAM CYCLER is set to what ever is required for flushing.

Filling the Tank

Before filling the tank with dielectric fluid it is a good idea to position the flushing attachments.

With the controls set the machine can now be made ready to begin the cut. The first thing to do is to fill the tank with dielectric fluid. Place the door and the upper guard on the front of the tank and secure in position. Fill the tank by placing the HOLD/DRAIN switch into the HOLD position and depressing the fill button. Fluid will enter the tank only when the button is held in. The fluid level should be brought up so that it safely covers the top of the workpiece. Now the BYE PASS valve should be opened to allow clean cool fluid into the tank during the cut.

With the fluid level established the fluid level safety switch should be set. This is done by adjusting the float to the level of the fluid in the tank. When this has been done correctly the ready light will be illuminated on the machine control box. The ready light will only illuminate if the RAM FEED switch is in the AUTO or LOCK position.

Starting the Cut

The workpiece and electrode are in position. The tank is full and the safety float is in position. The ready light is on. The setup is ready for the EDM process to begin. To start the cut depress the switch labeled ON/ADVANCE. **THIS GIVES CUTTING POWER TO THE RAM OF THE EDM MACHINE.** If the electrode is a large distance away from the workpiece surface the ram can be made to feed in a rapid mode by holding in the ON/ADVANCE button. Be very careful not to smash the electrode into the workpiece.

As the electrode begins to spark it will be necessary to stabilize the cut. The controls used to stabilize the cut are the SERVO SPEED knob, and the GAP ADJUST knob. The cut is fine tuned by turning these knobs and watching the EFFICIENCY METER, the Trav-a-dial, and the gap light located in the monitor area of the power supply.

The efficiency meter should read as high as possible without causing the gap light to illuminate. This is done by adjusting the SERVO SPEED and the GAP ADJUST controls.

The Trav-a-dial needle should have a slight (.0005") but rapid bounce. This is done by adjusting the SERVO SPEED.

Once the cut has been stabilized using the SERVO SPEED and GAP ADJUST controls then the GAP INITIATION and ELECTRODE switches may be adjusted to try and achieve even greater efficiency on the meter. (Refer to UNIT 8 for more information.)

The machine tool is capable of running unattended. This may not be a good idea for the first one or two times you use the machine. As the cut progresses it is a good idea to keep a watch on the MONITOR AREA of the power supply control. This area will detect any problems with the machining conditions.

Alarms

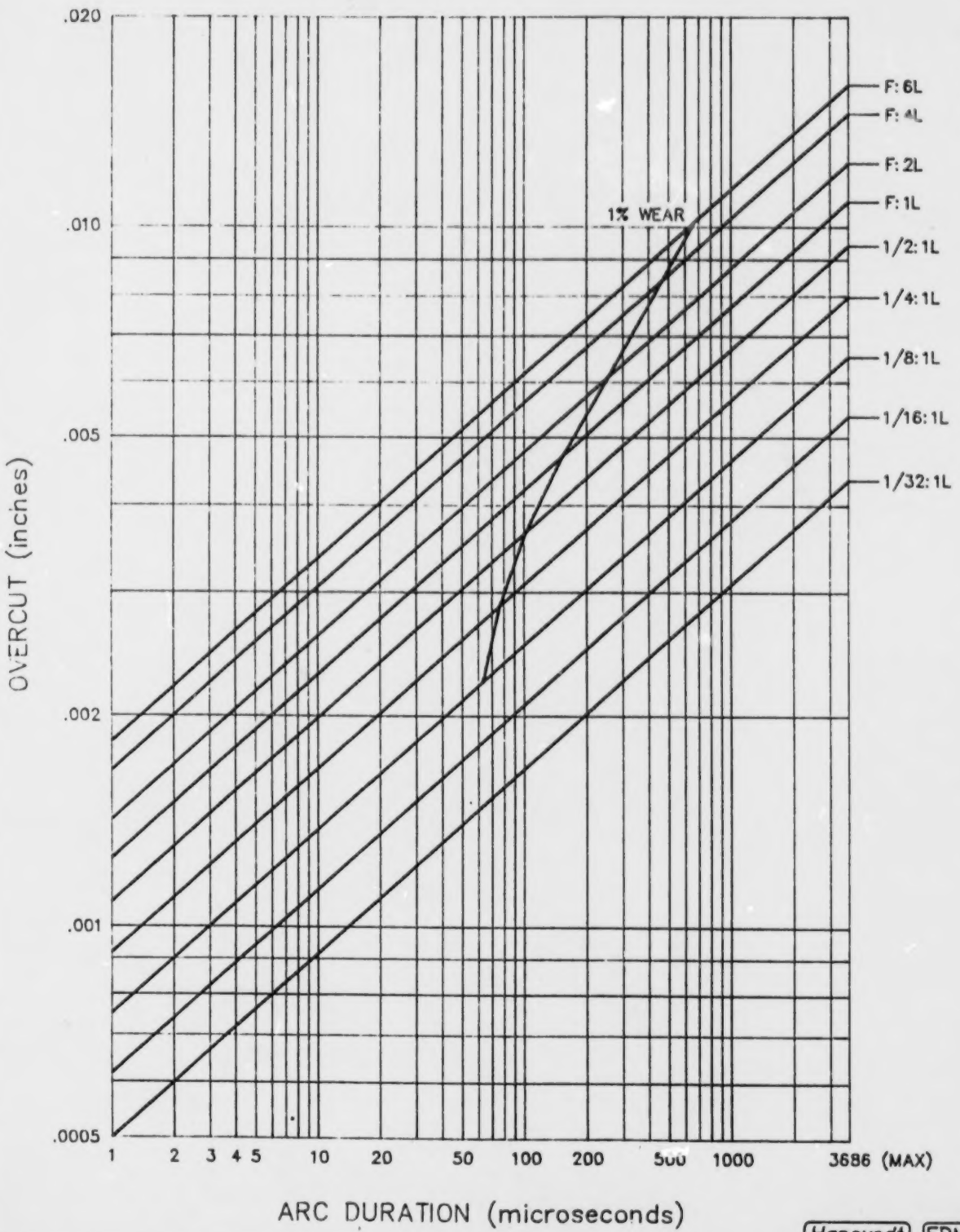
If the alarm should sound during machining look at the monitor area of the power supply control to determine the reason. The alarm can be shut off by depressing the re-set button in the monitor area.

BEST COPY AVAILABLE

Appendix 1

OVERCUT, ARC DURATION, % ON-TIME, AND CUTTING SPEED GRAPHS

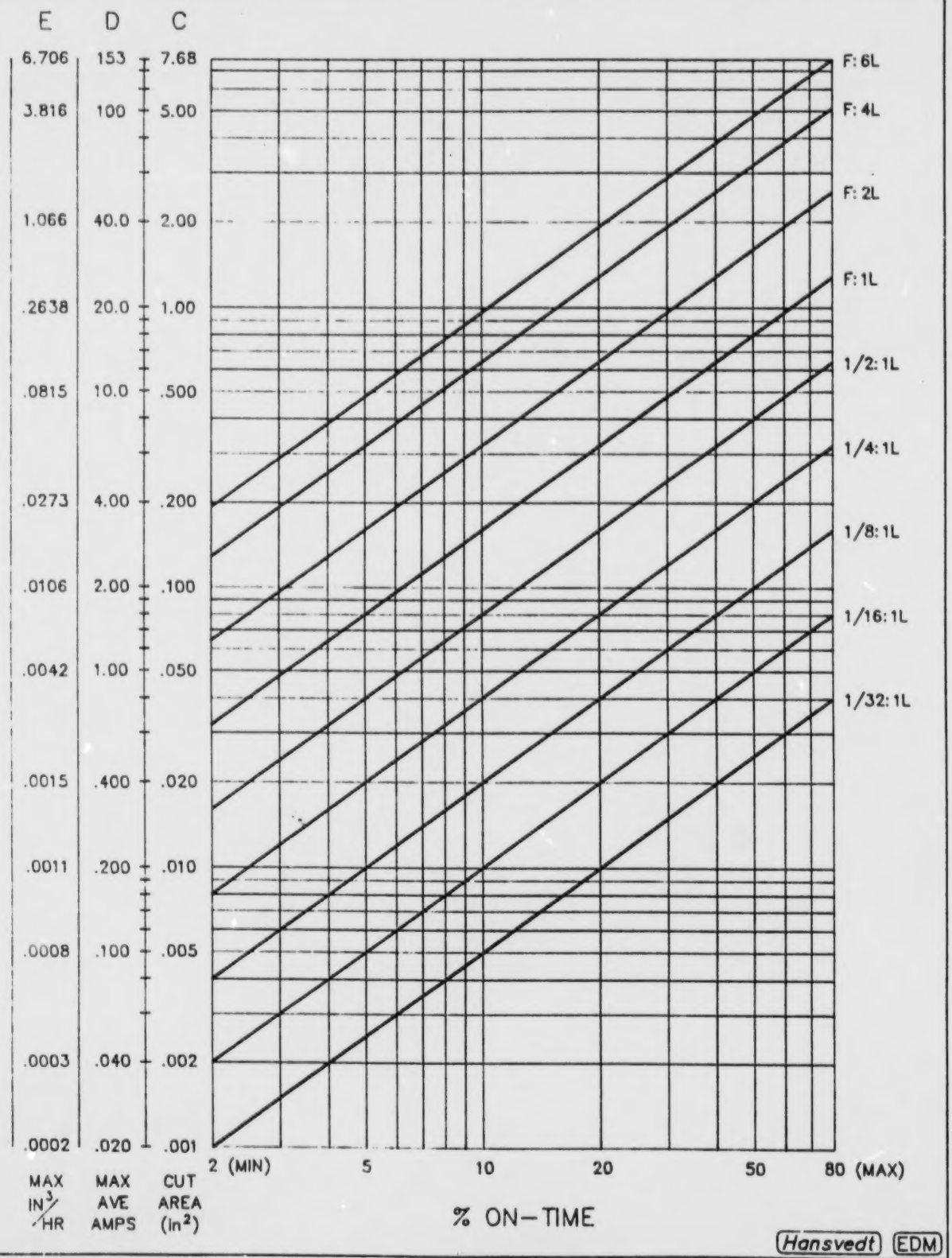
GRAPH A	OVERCUT	GRAPHITE (+) / STEEL (−)



Hansvedt EDM

7/80

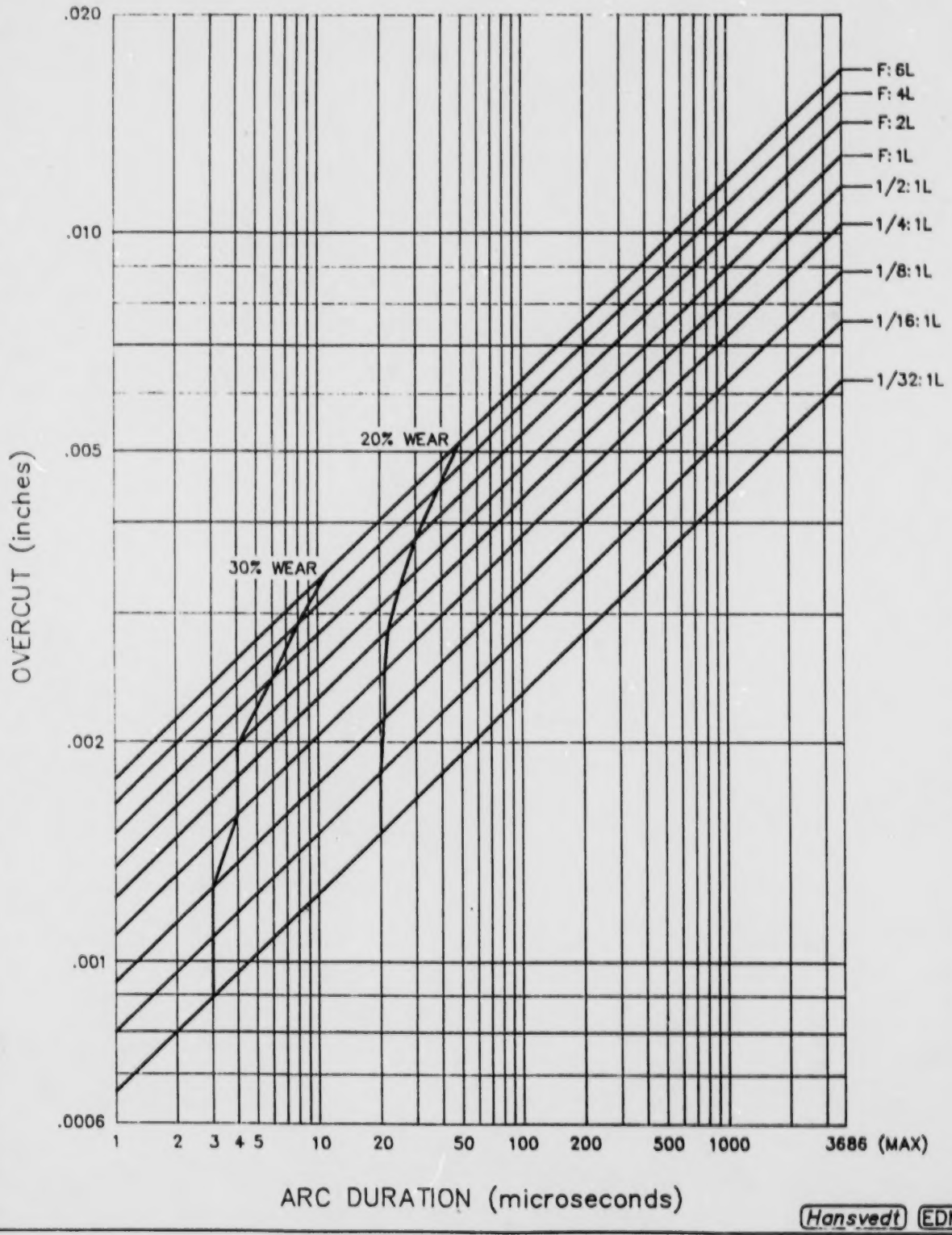
GRAPH C–E	CUTTING SPEED	GRAPHITE (+) / STEEL (–)



Hansvedt EDM

7/89

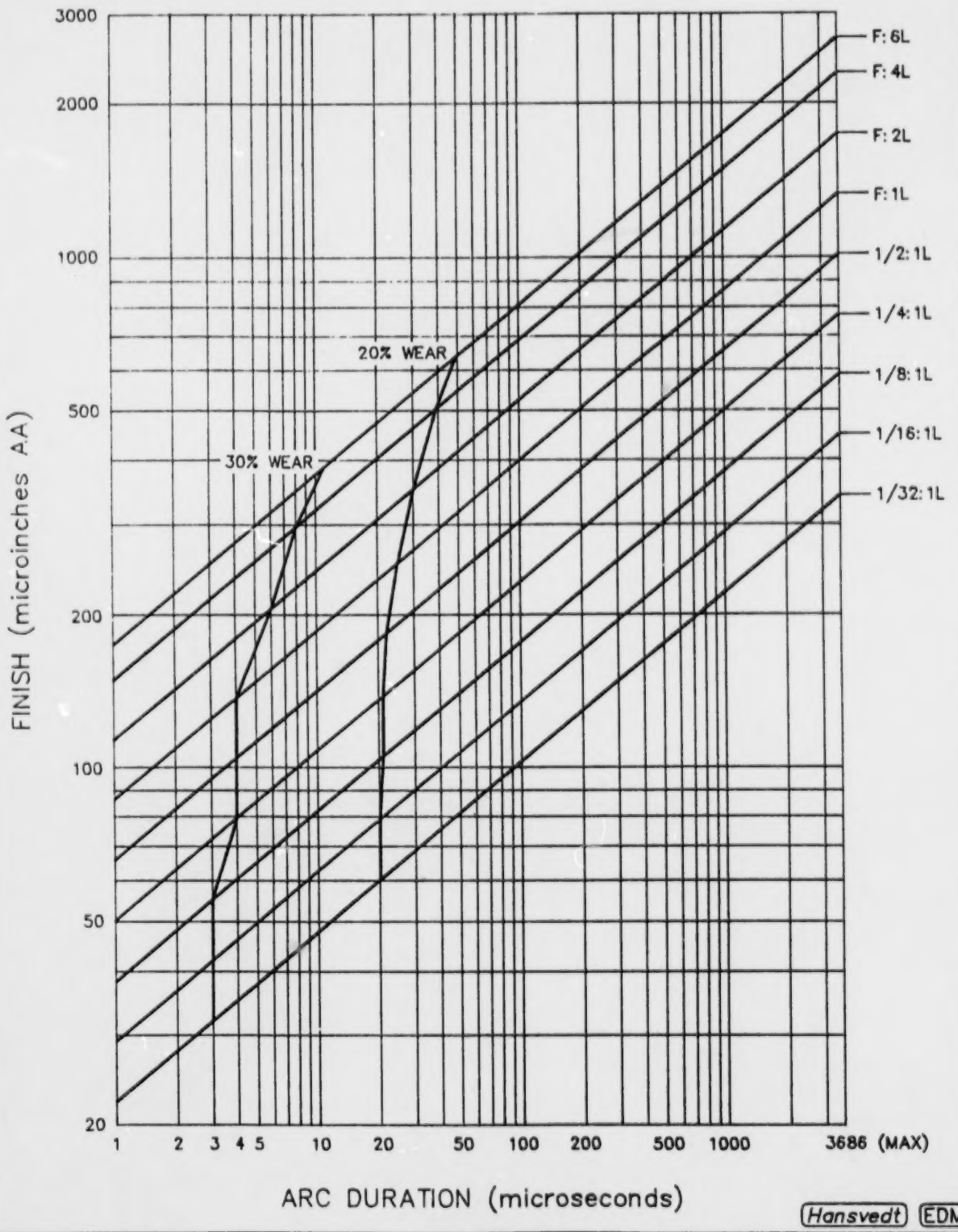
GRAPH A	OVERCUT	GRAPHITE (−) / STEEL (+)



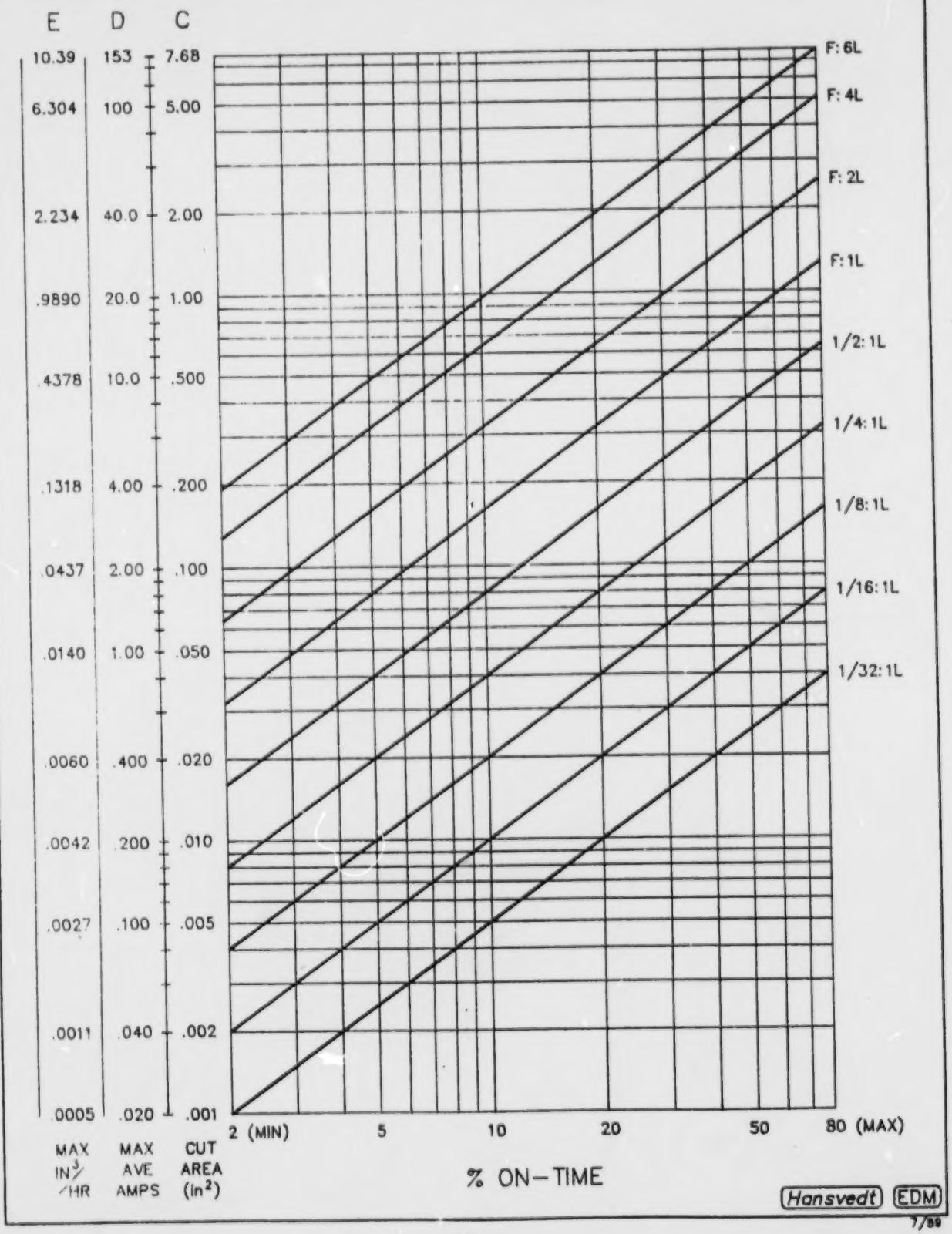
Hansvedt EDM

7/89

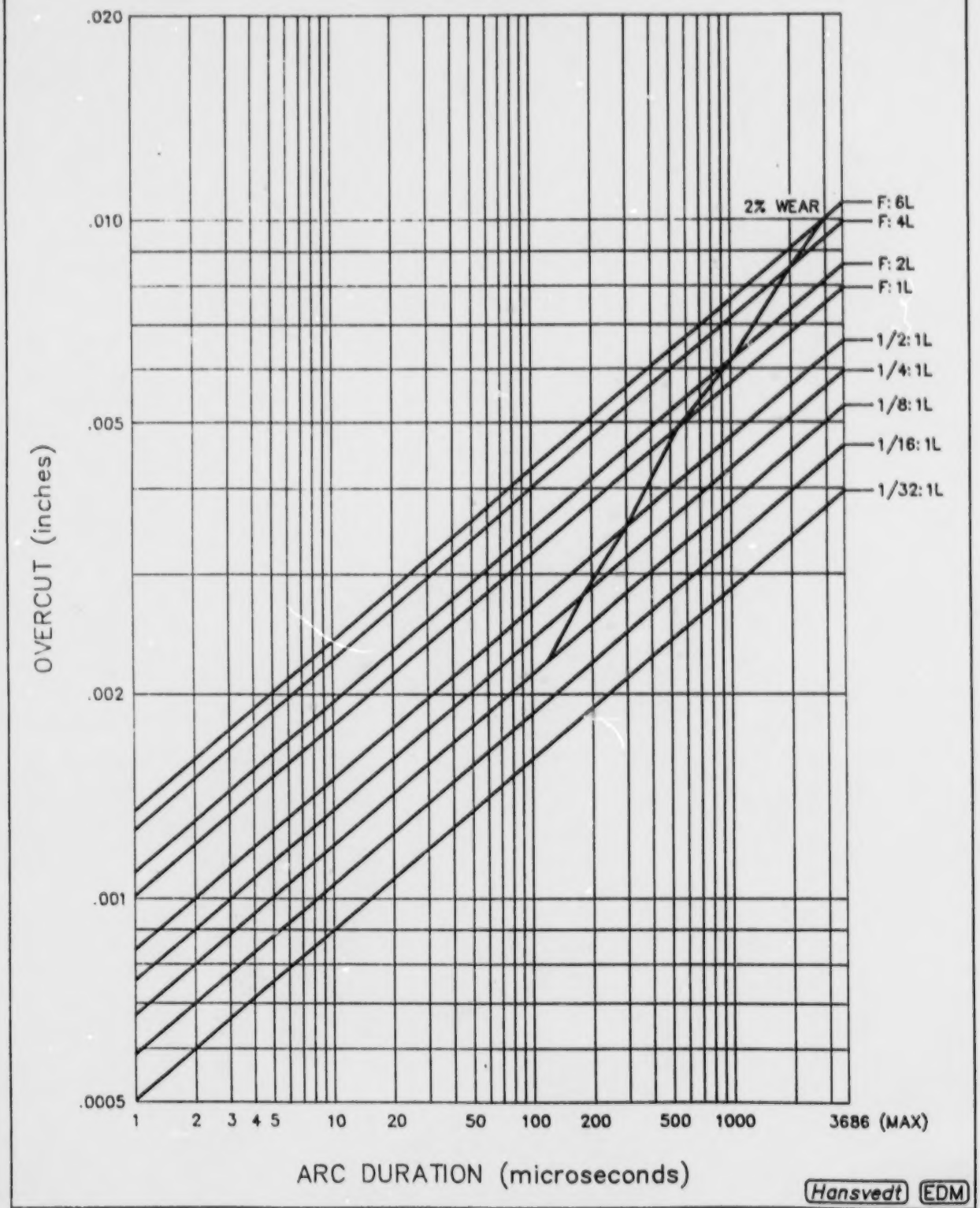
GRAPH B	FINISH	GRAPHITE (−) / STEEL (+)



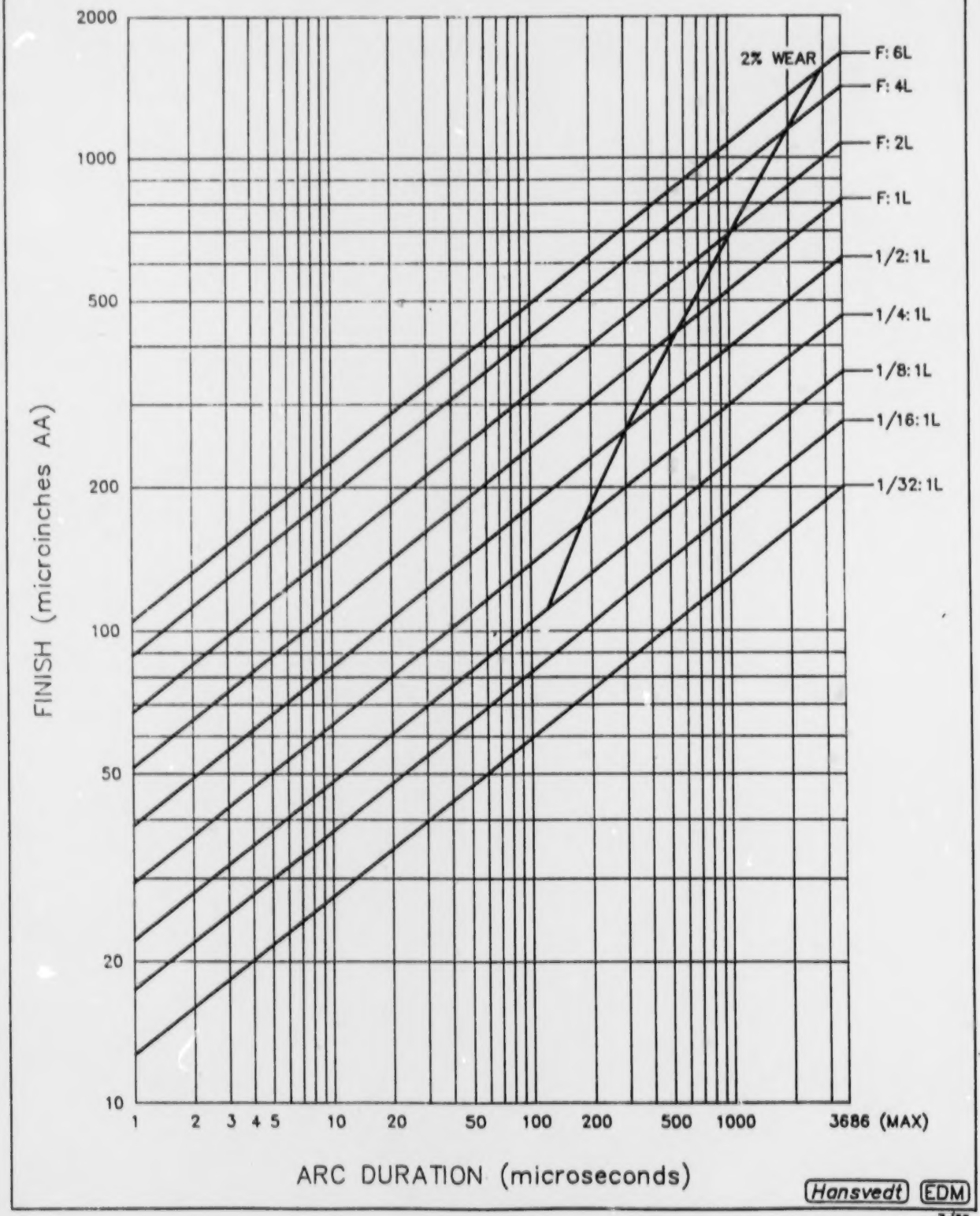
GRAPH C–E	CUTTING SPEED	GRAPHITE (–) / STEEL (+)



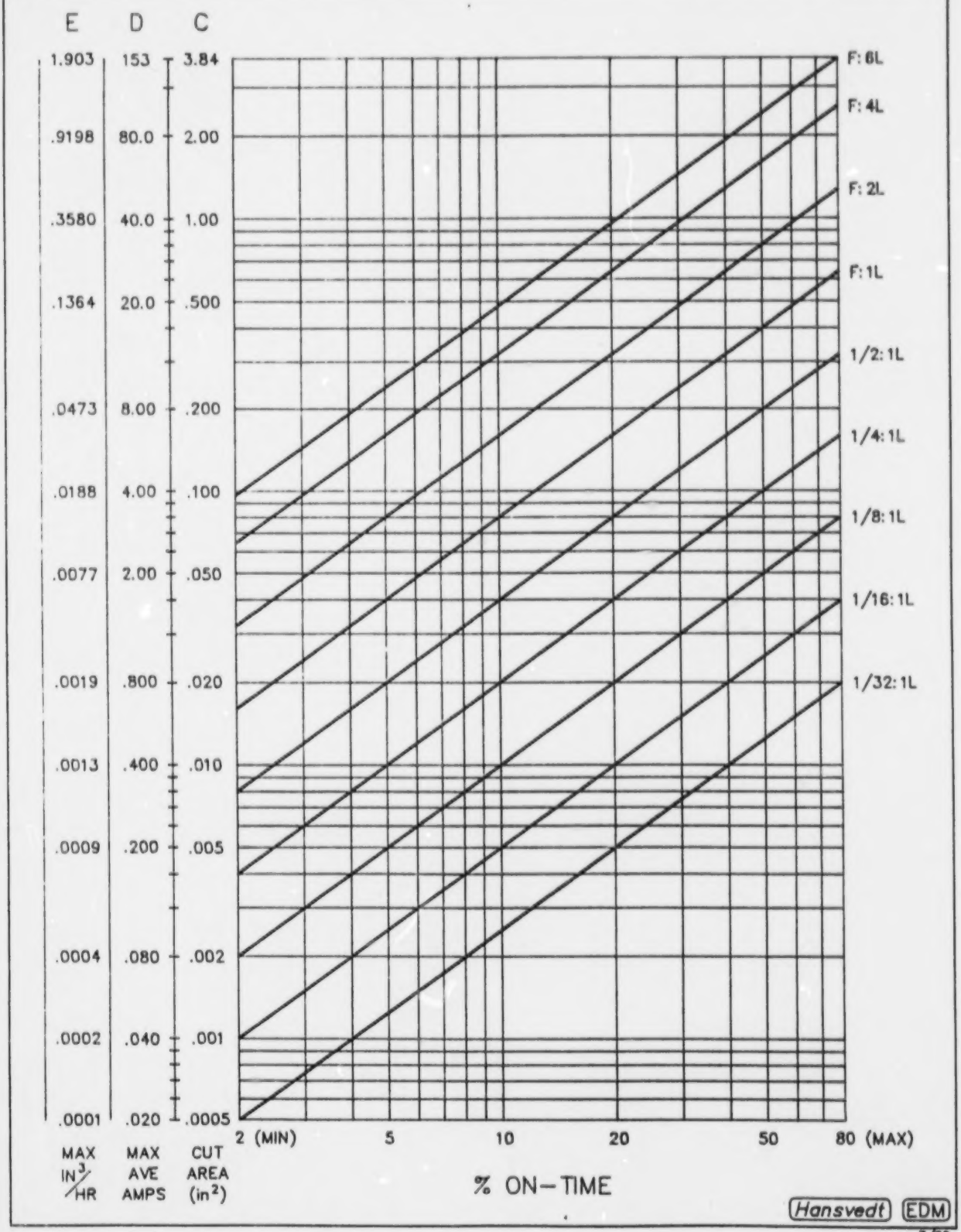
GRAPH A	OVERCUT	COPPER (+) / STEEL (−)



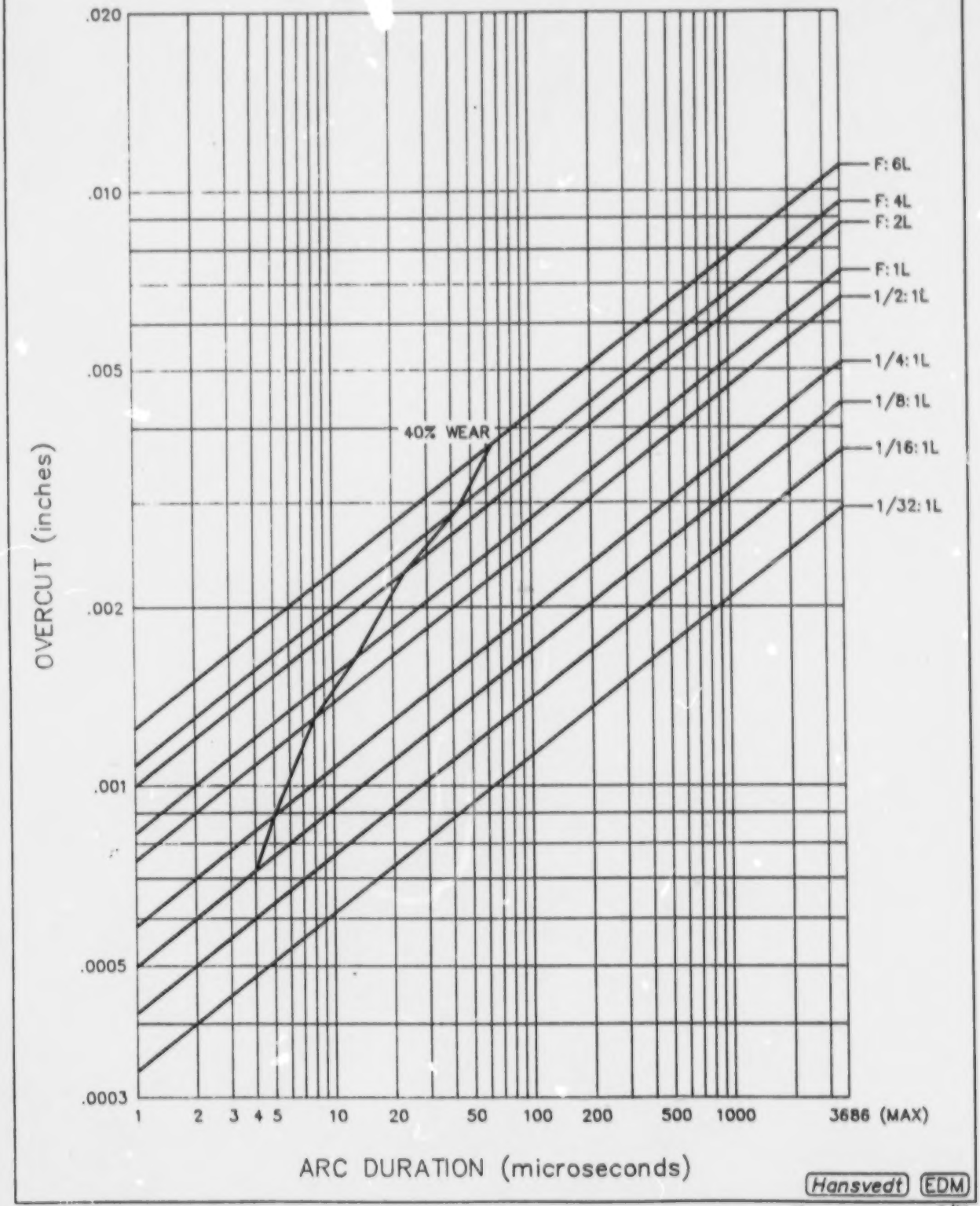
GRAPH B	FINISH	COPPER (+) / STEEL (−)



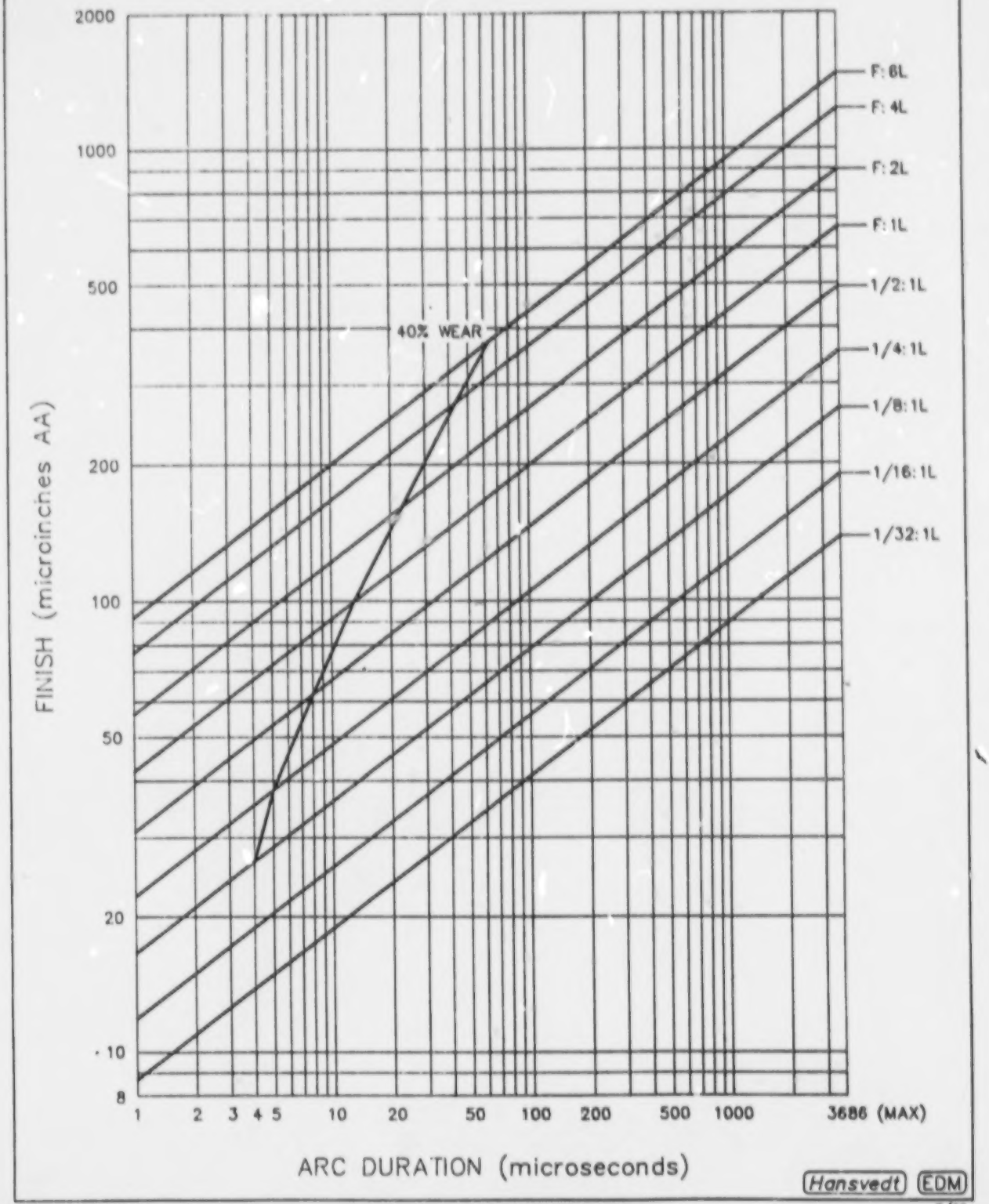
GRAPH C–E	CUTTING SPEED	COPPER (+) / STEEL (–)



GRAPH A	OVERCUT	COPPER (−) / STEEL (+)

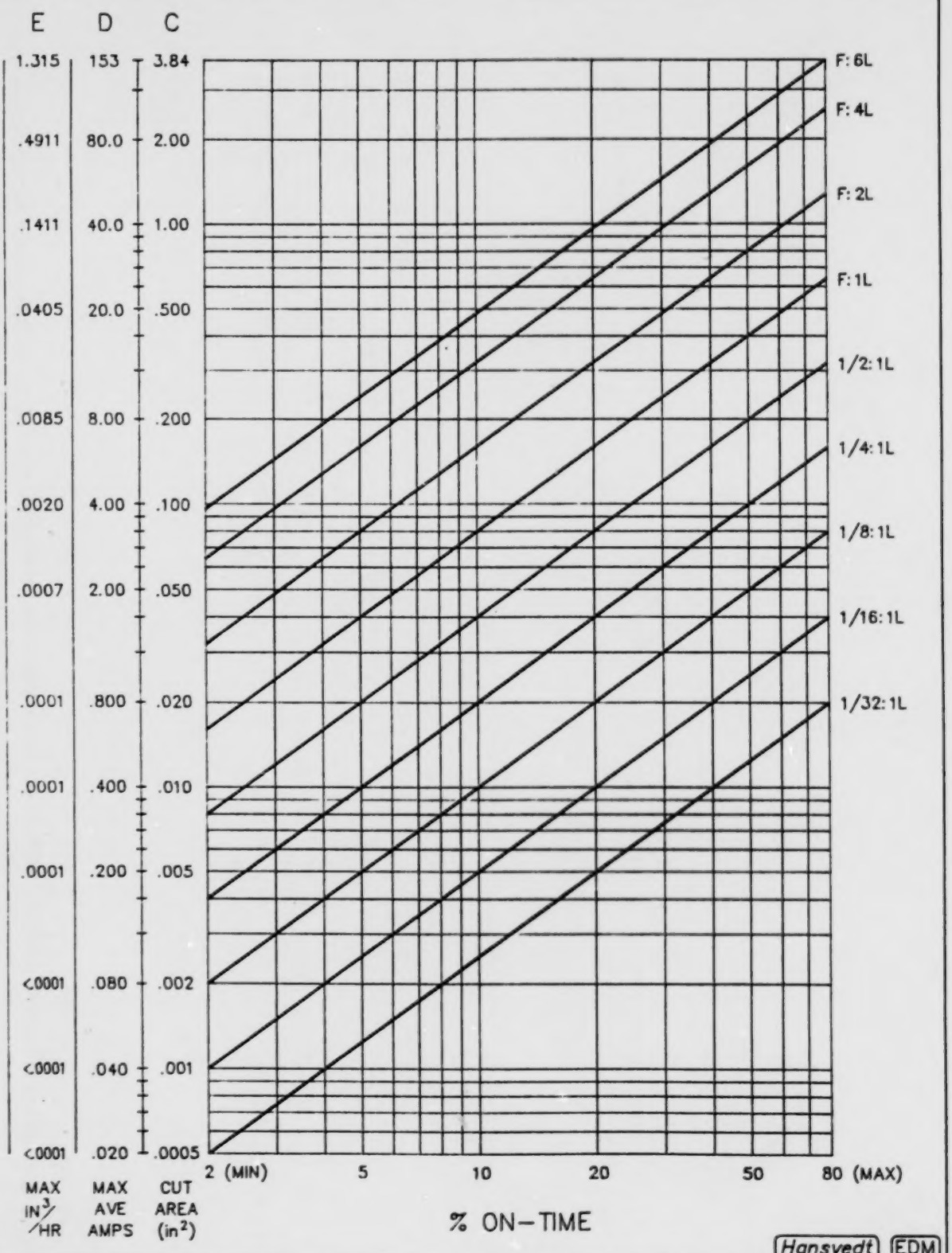


GRAPH B	FINISH	COPPER (−) / STEEL (+)

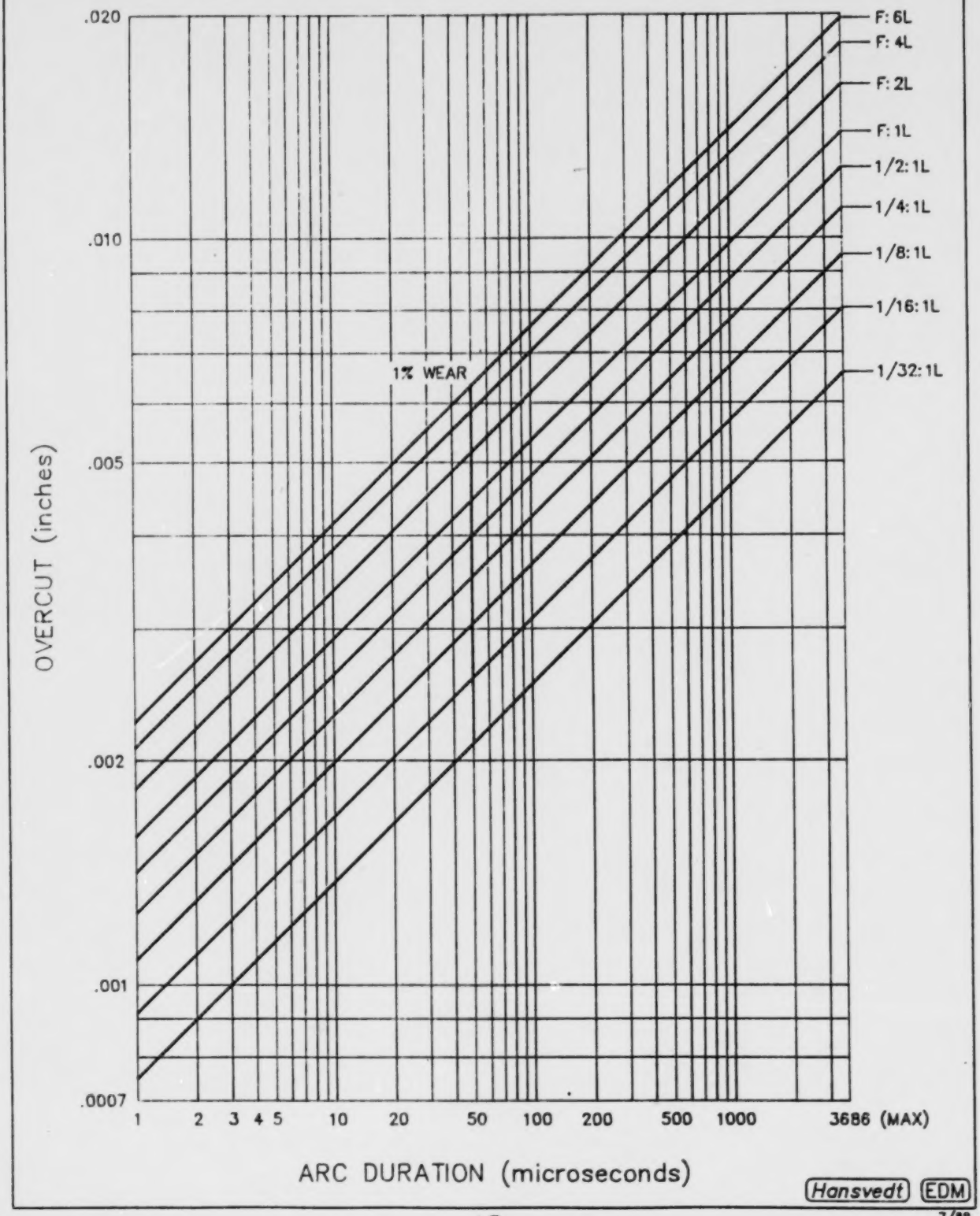


7/89

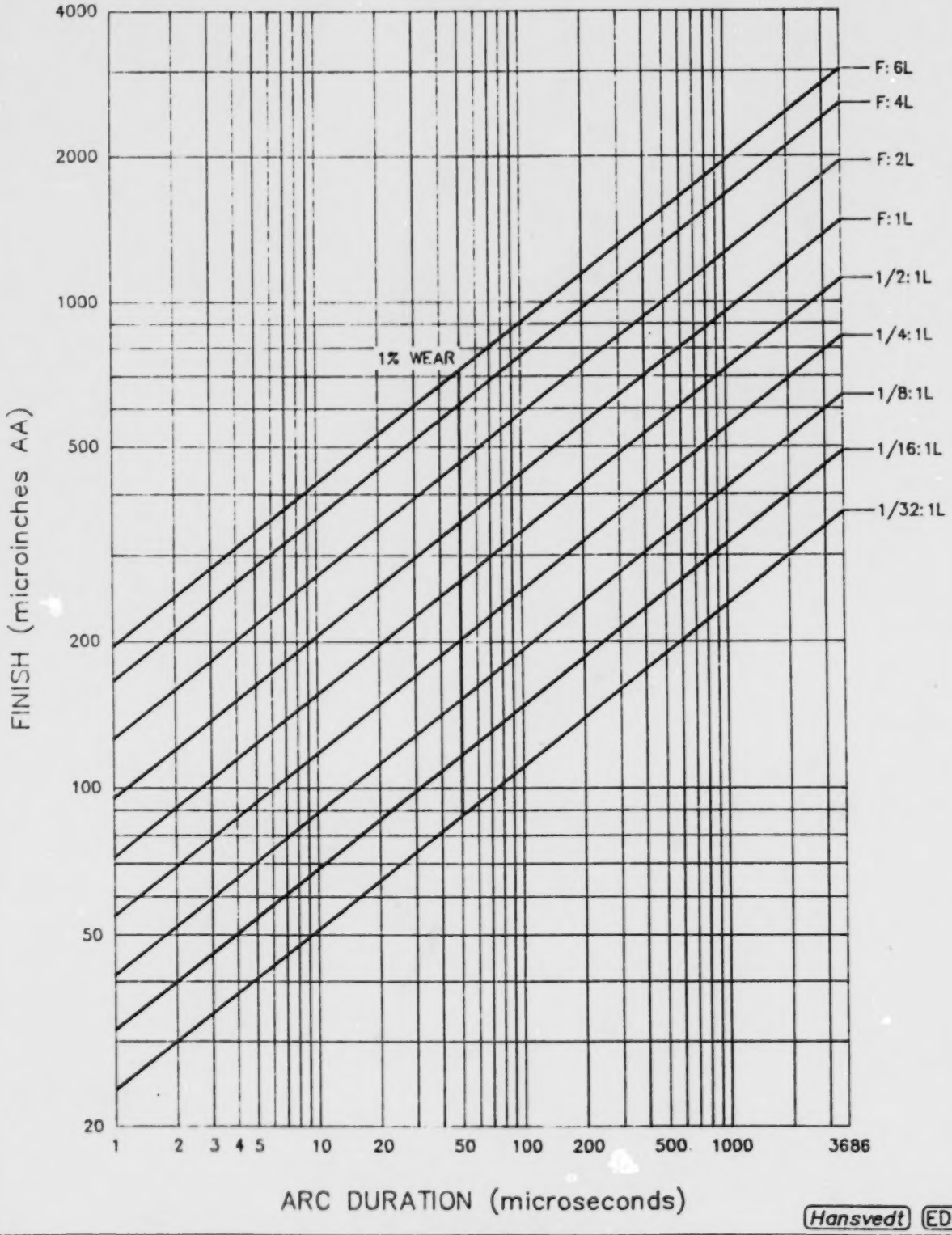
GRAPH C–E	CUTTING SPEED	COPPER (–) / STEEL (+)



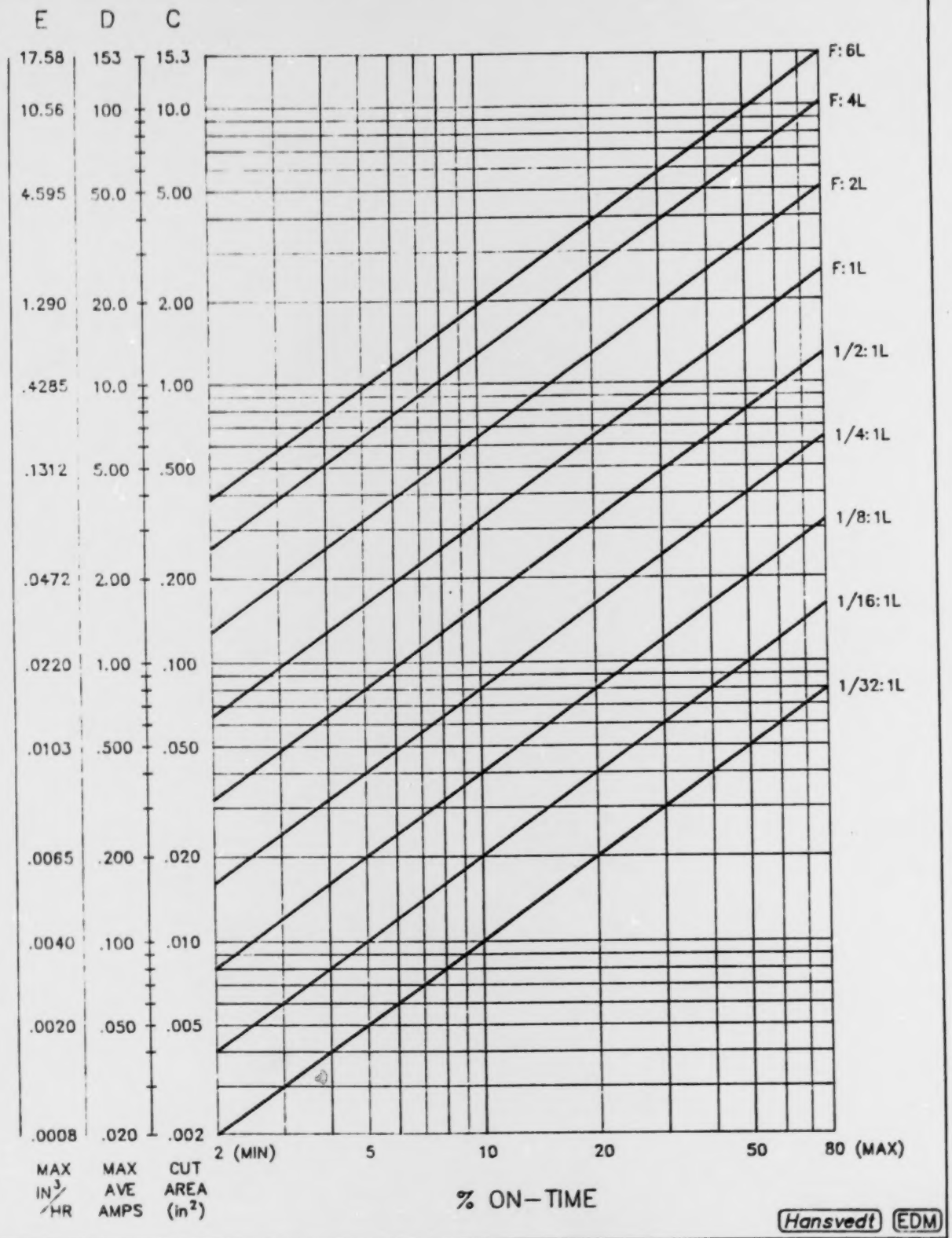
GRAPH A	OVERCUT	GRAPHITE (+) / ALUMINUM (−)



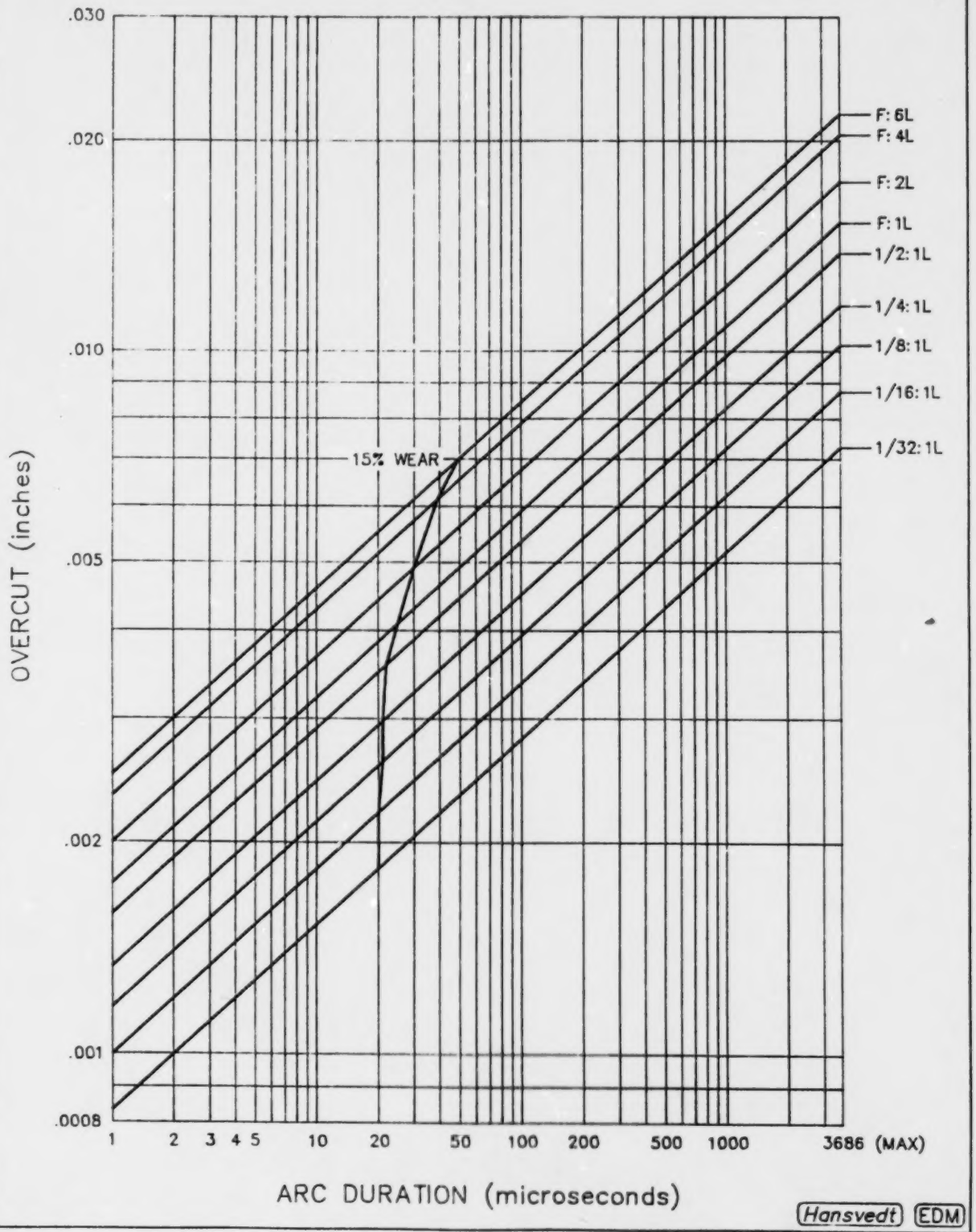
GRAPH B	FINISH	GRAPHITE (+) / ALUMINUM (−)



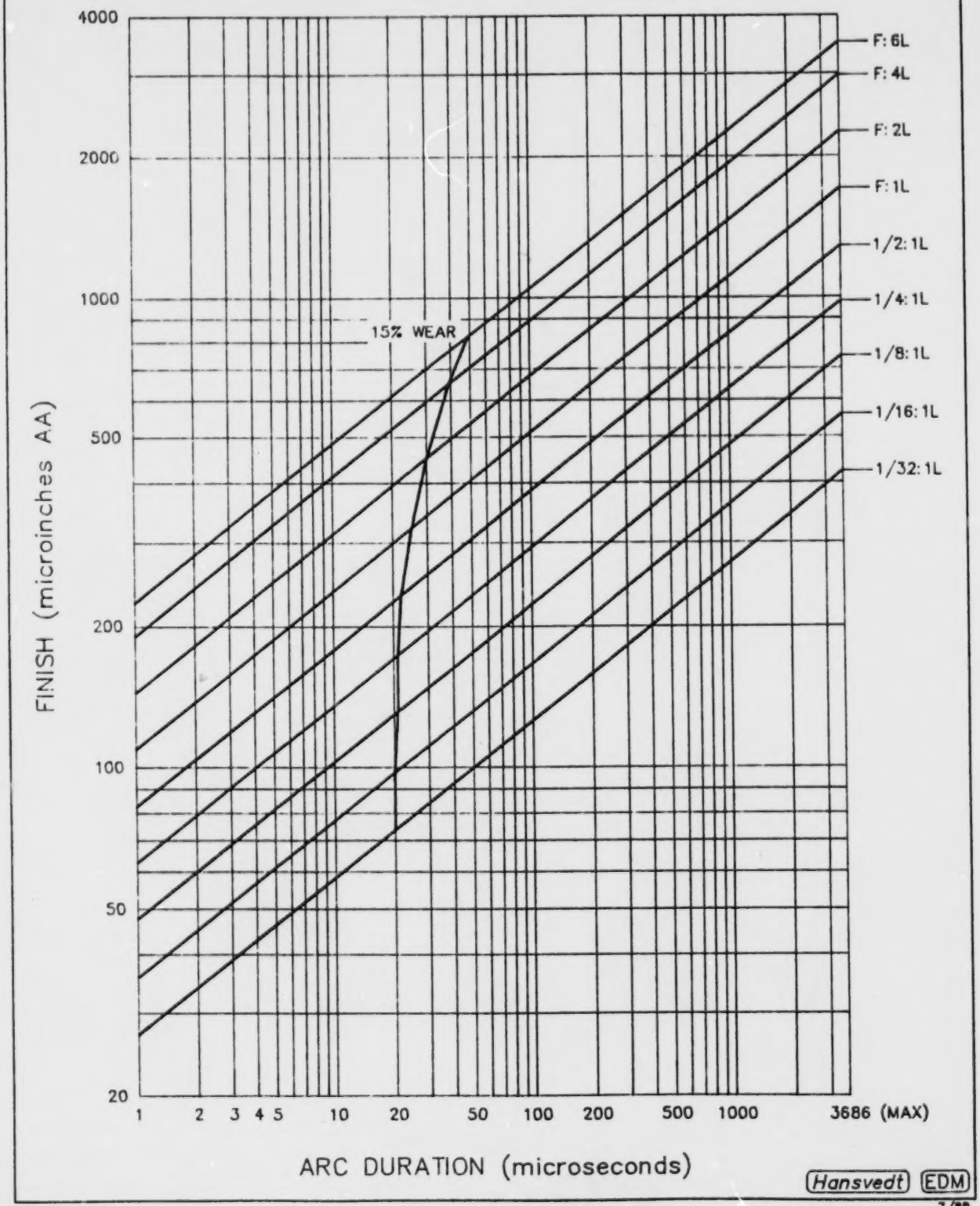
GRAPH C–E	CUTTING SPEED	GRAPHITE (+) / ALUMINUM (–)



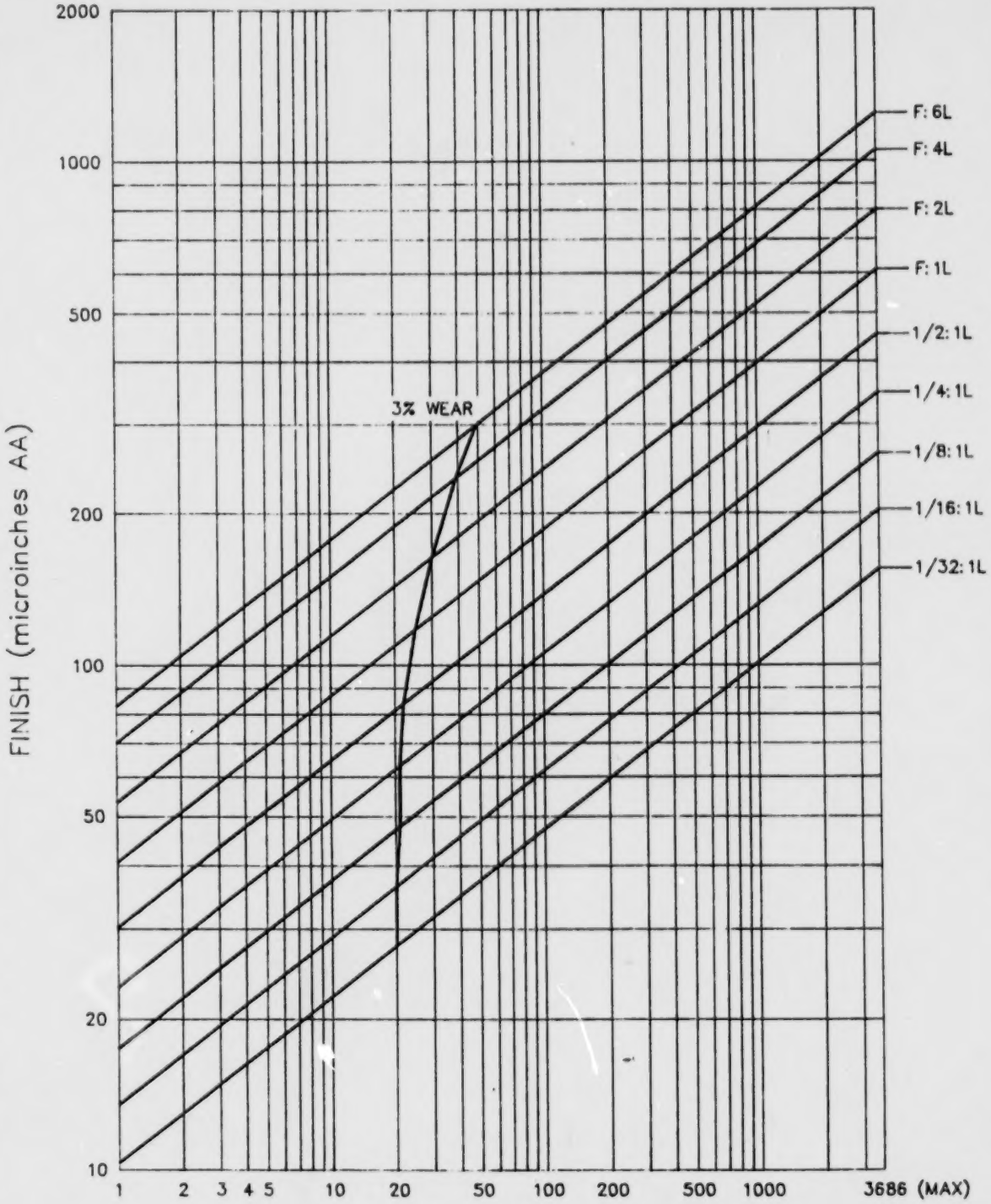
GRAPH A	OVERCUT	GRAPHITE (−) / ALUMINUM (+)



GRAPH B	FINISH	GRAPHITE (−) / ALUMINUM (+)



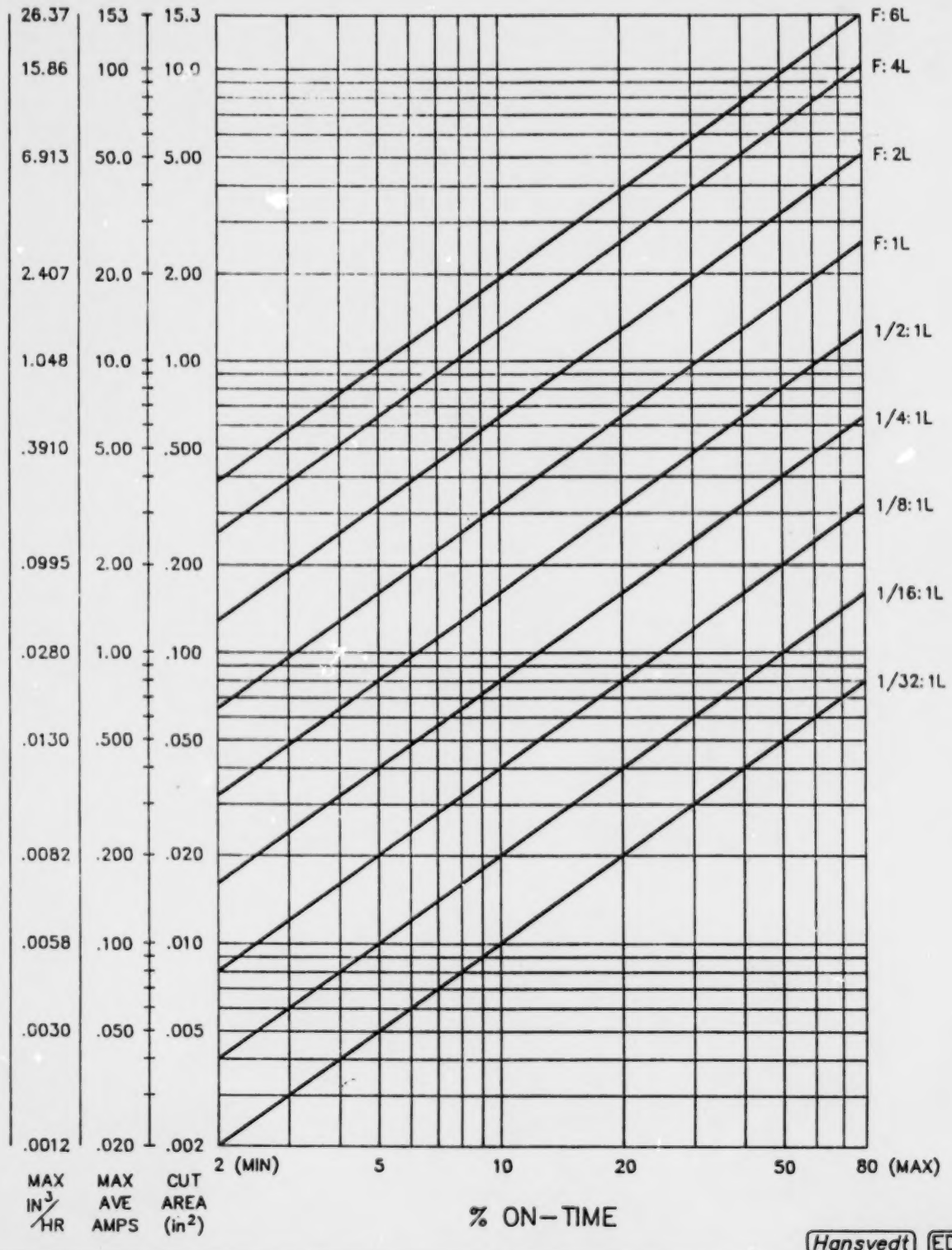
GRAPH B	FINISH	COPPER–TUNGSTEN (+) / STEEL (–)



Hansvedt EDM

7/89

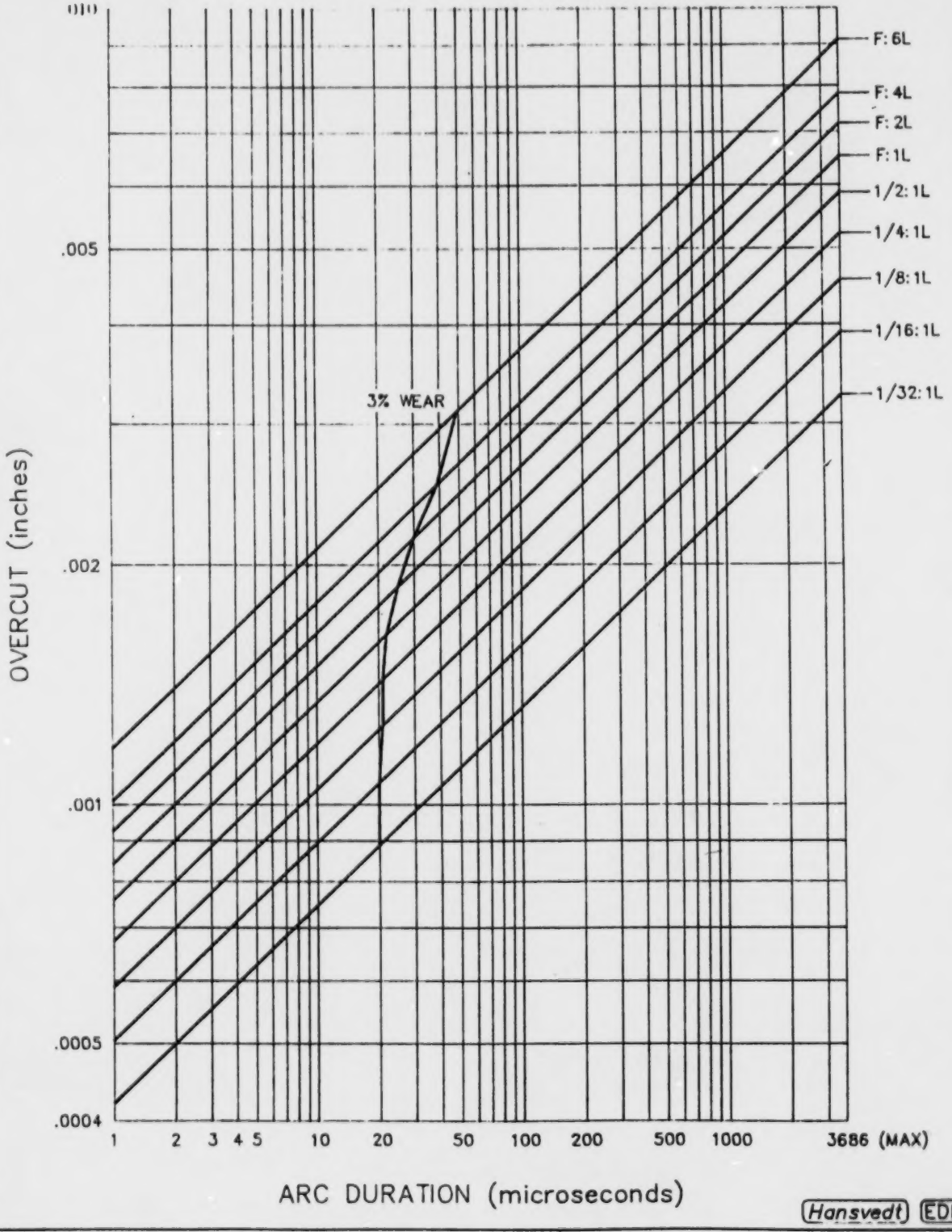
GRAPH C–F	CUTTING SPEED	GRAPHITE (–) / ALUMINUM (+)



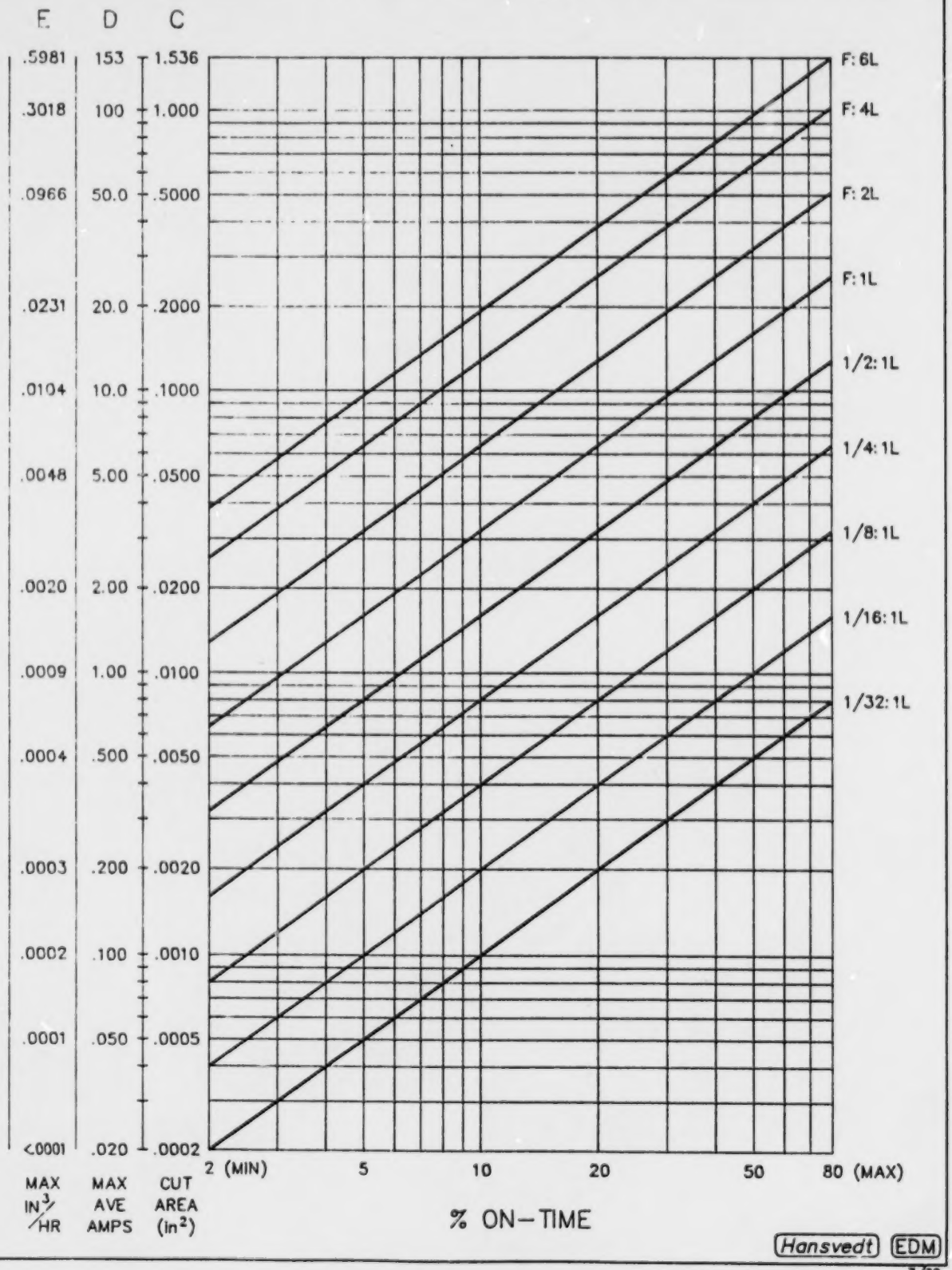
Hansvedt EDM

7/89

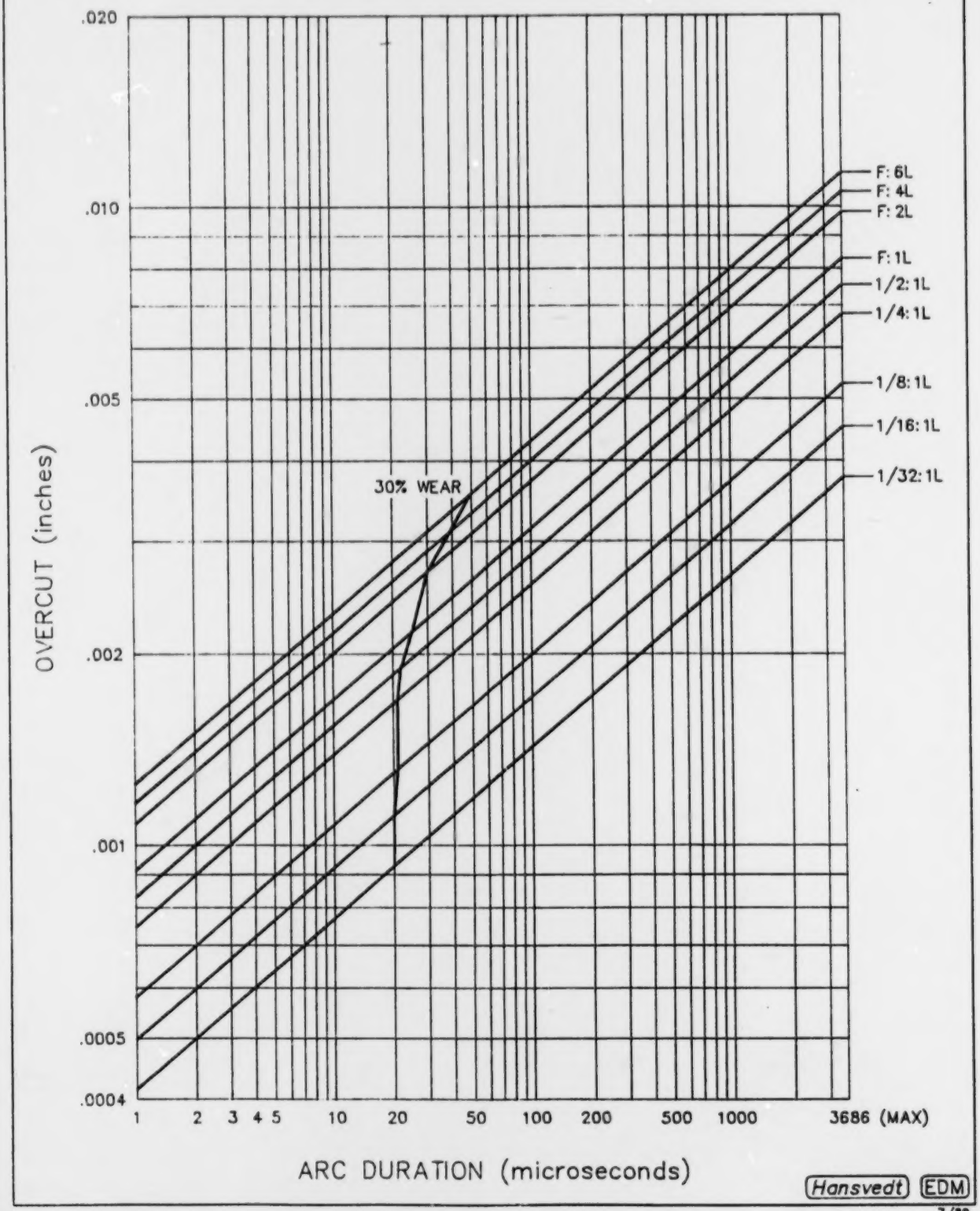
GRAPH A	OVERCUT	COPPER–TUNGSTEN (+) / STEEL (–)



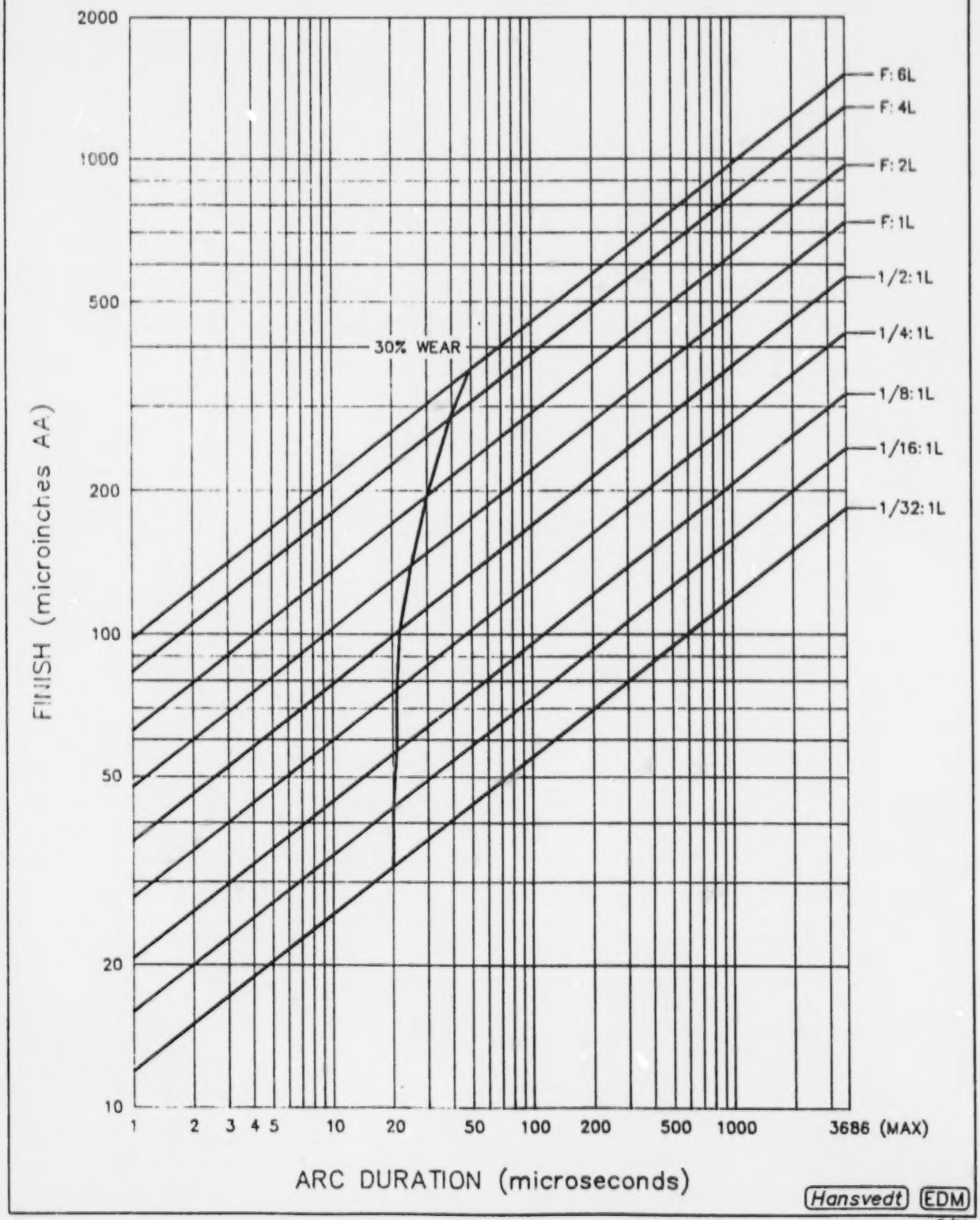
GRAPH C–E	CUTTING SPEED	COPPER–TUNGSTEN (+) / STEEL (–)



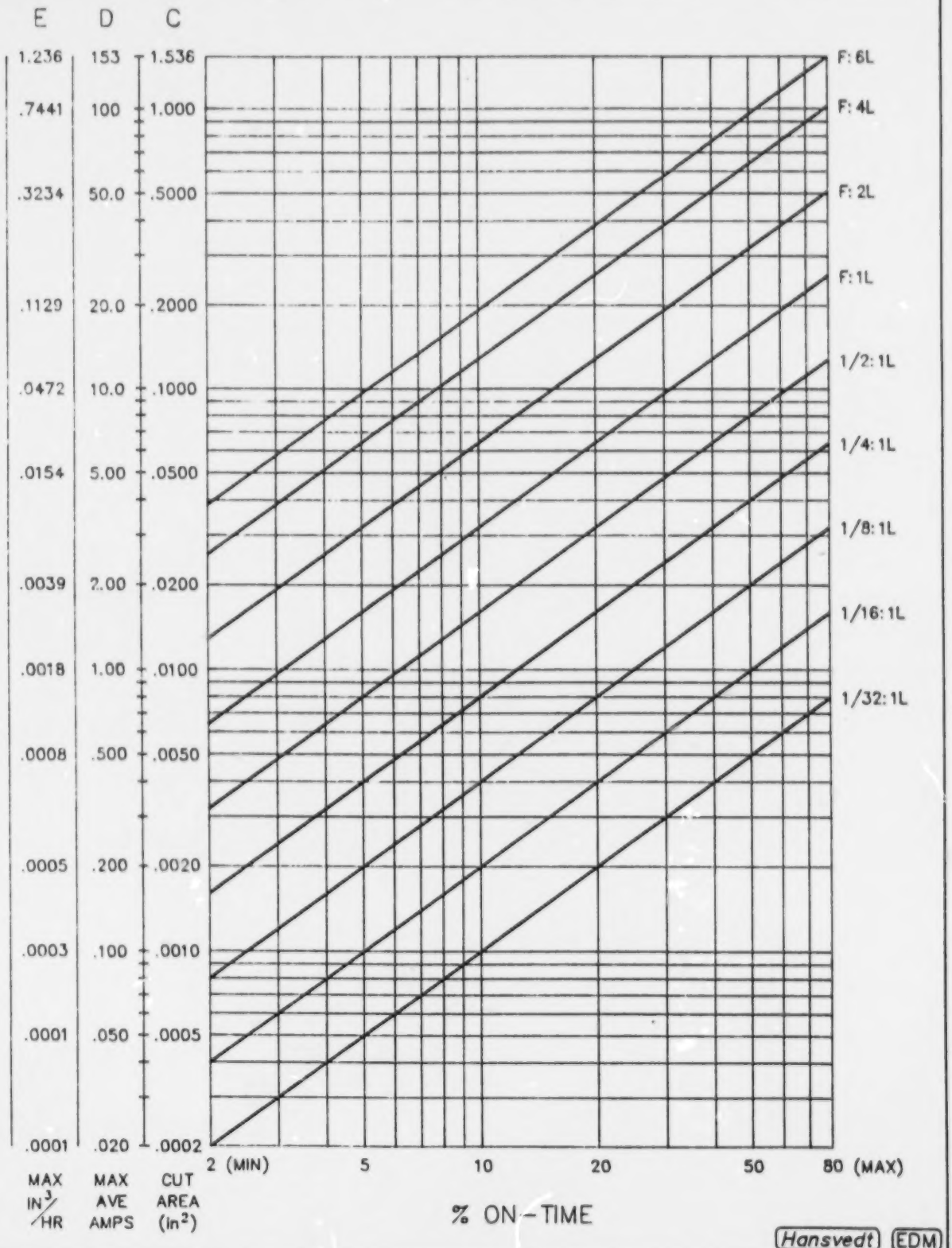
GRAPH A	OVERCUT	COPPER–TUNGSTEN (–) / STEEL (+)



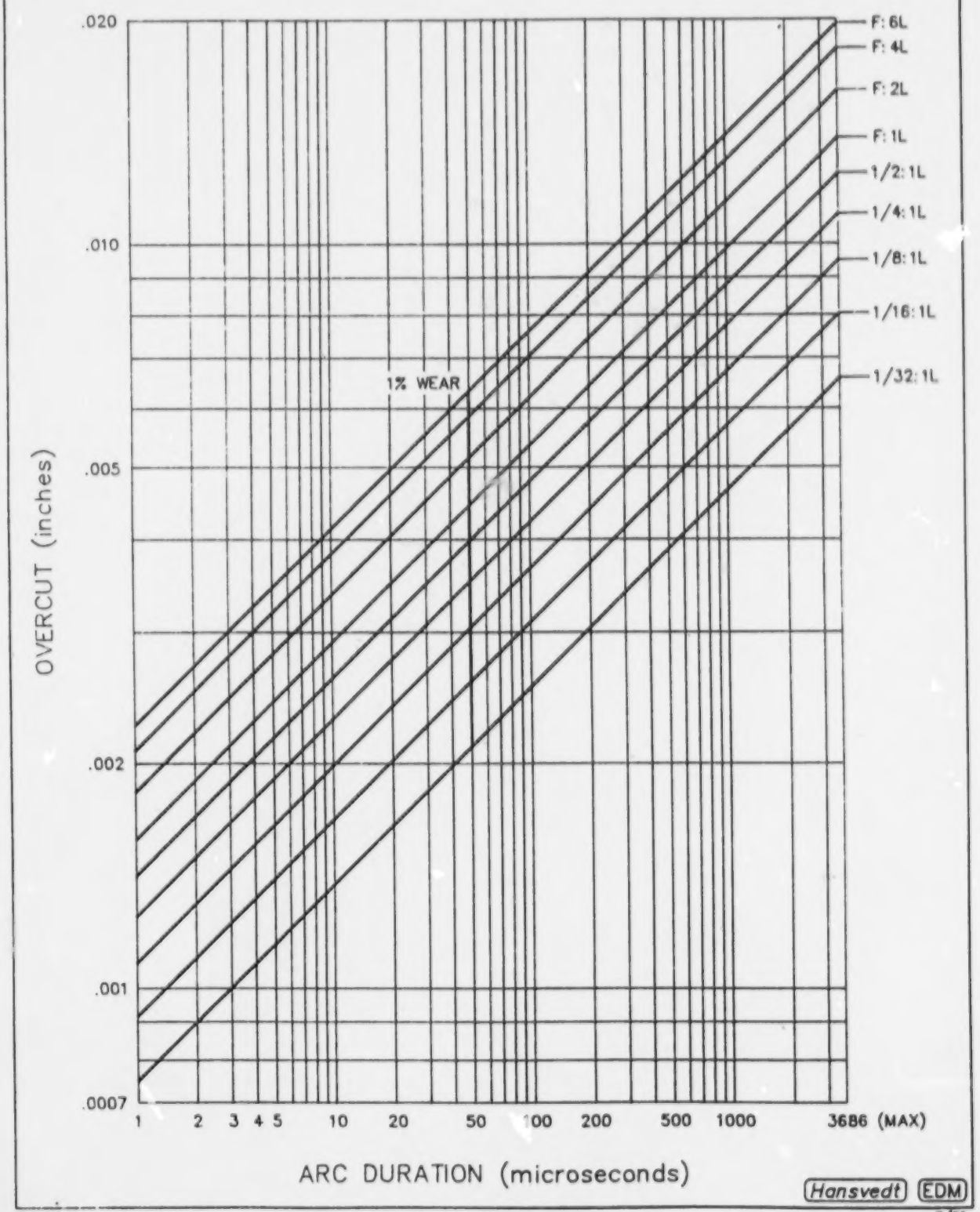
GRAPH B	FINISH	COPPER–TUNGSTEN (–) / STEEL (+)



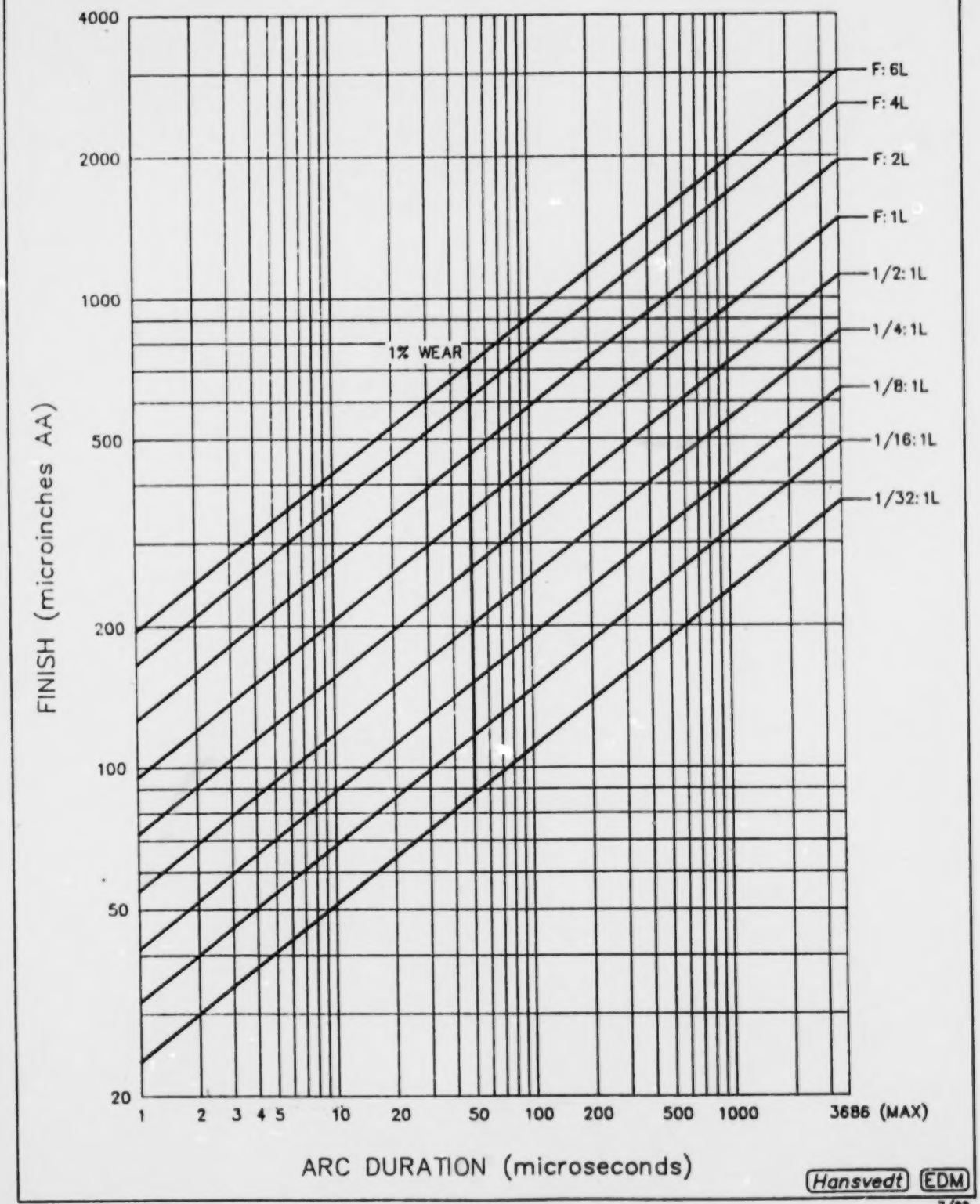
GRAPH C–E	CUTTING SPEED	COPPER–TUNGSTEN (–) / STEEL (+)



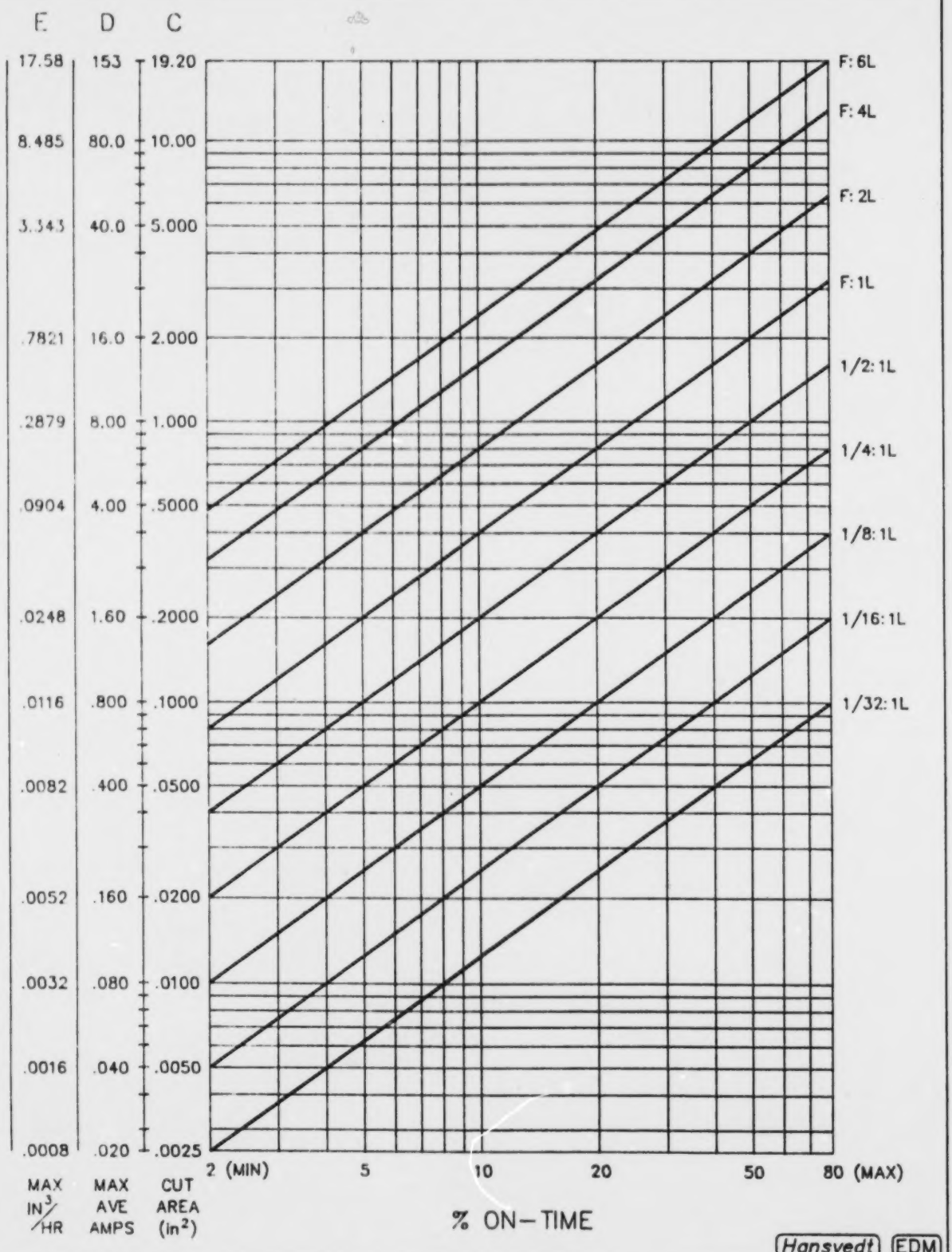
GRAPH A	OVERCUT	GRAPHITE (+) / TITANIUM (−)



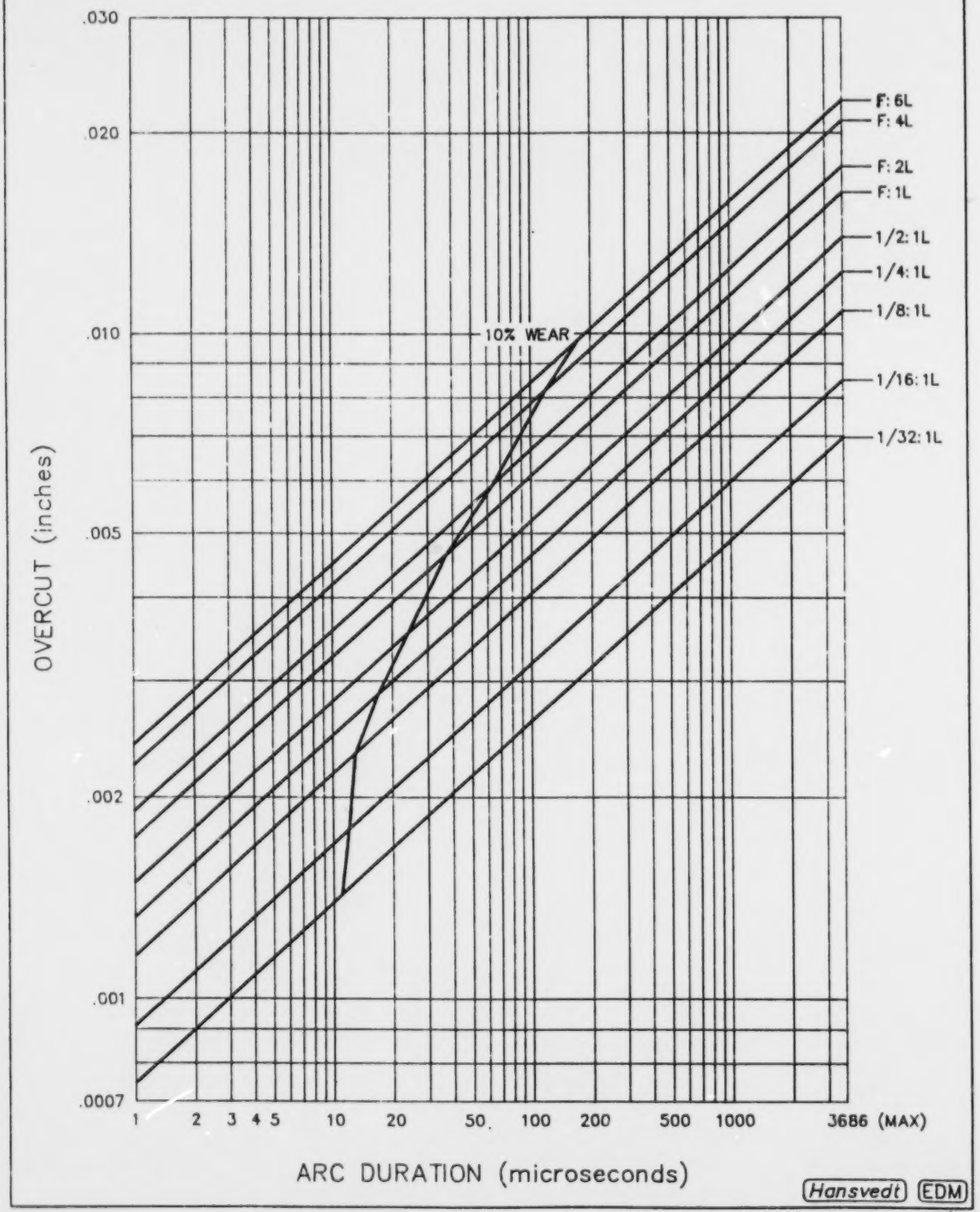
GRAPH B	FINISH	GRAPHITE (+) / TITANIUM (−)



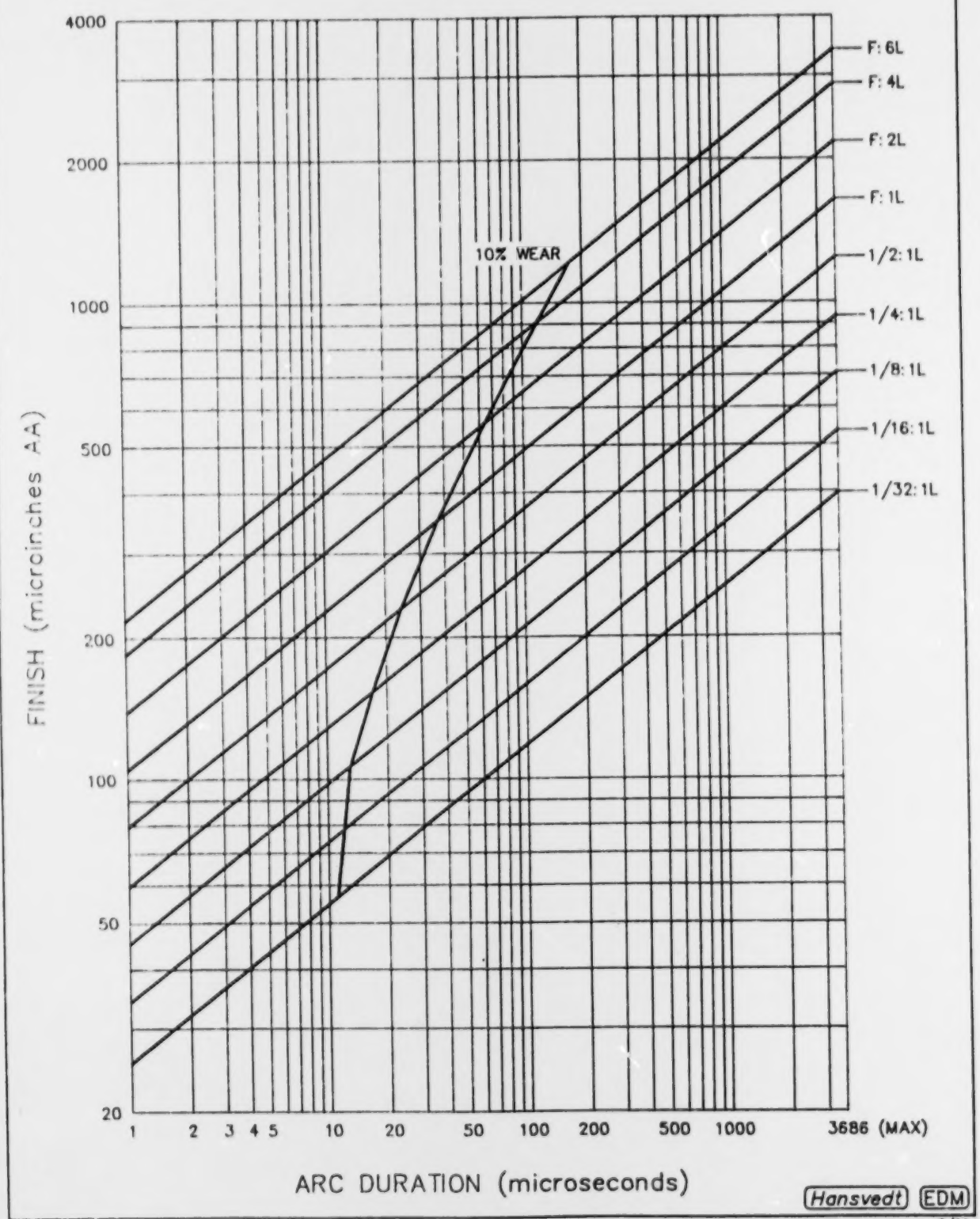
GRAPH C–E	CUTTING SPEED	GRAPHITE (+) / TITANIUM (–)



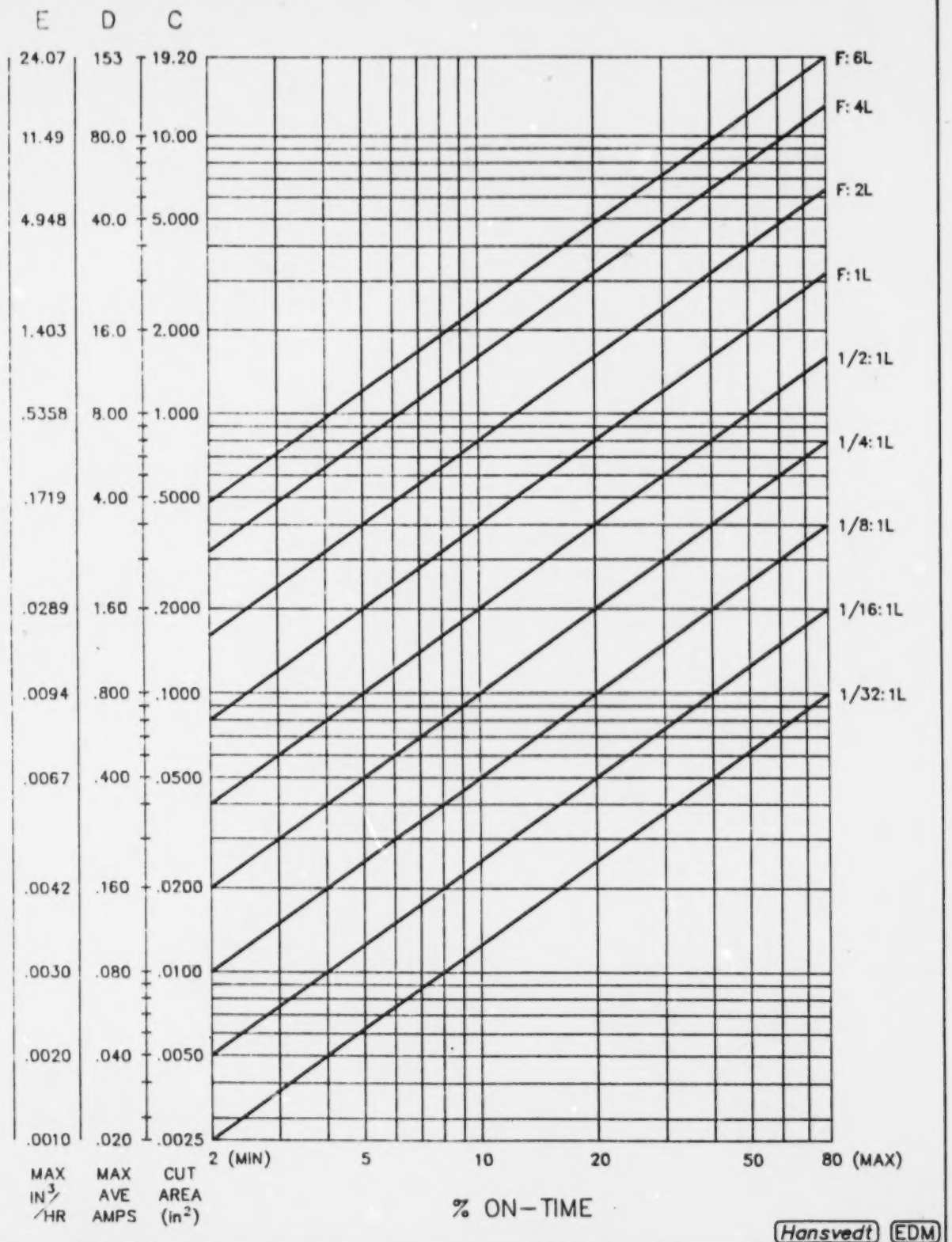
GRAPHITE	OVERCUT	GRAPHITE (−) / TITANIUM (+)



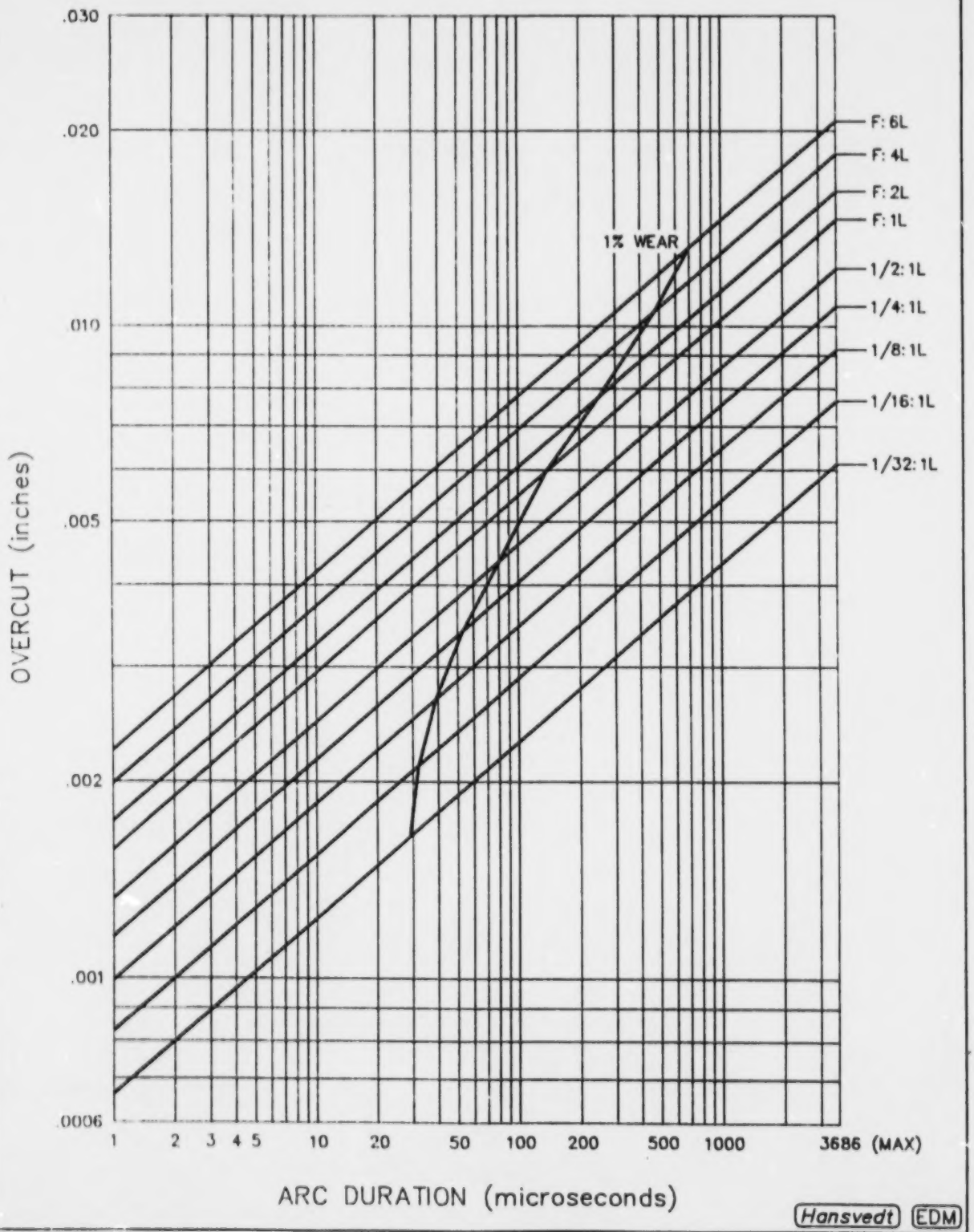
GRAPH B	FINISH	GRAPHITE (−) / TITANIUM (+)



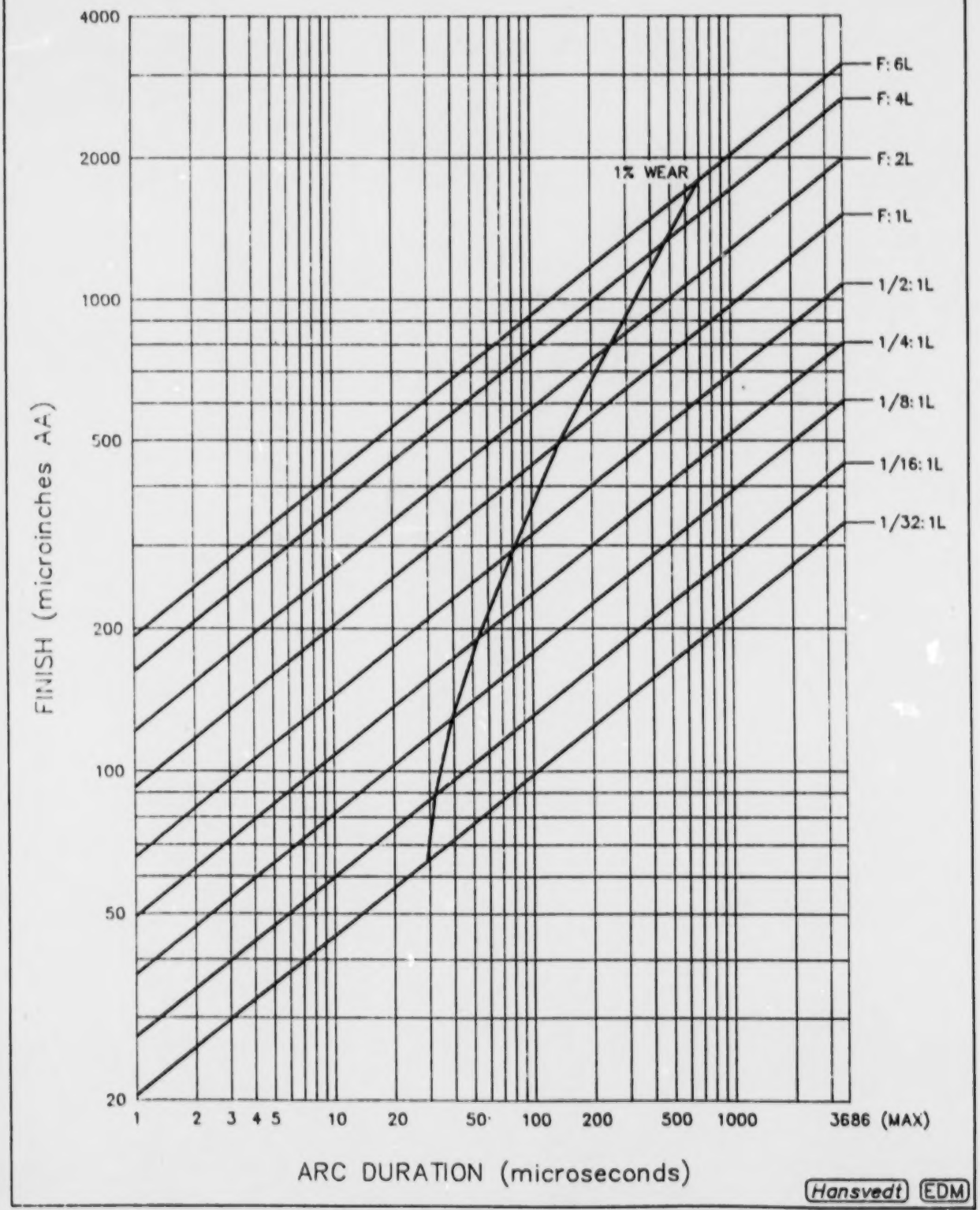
GRAPH C–E	CUTTING SPEED	GRAPHITE (–) / TITANIUM (+)



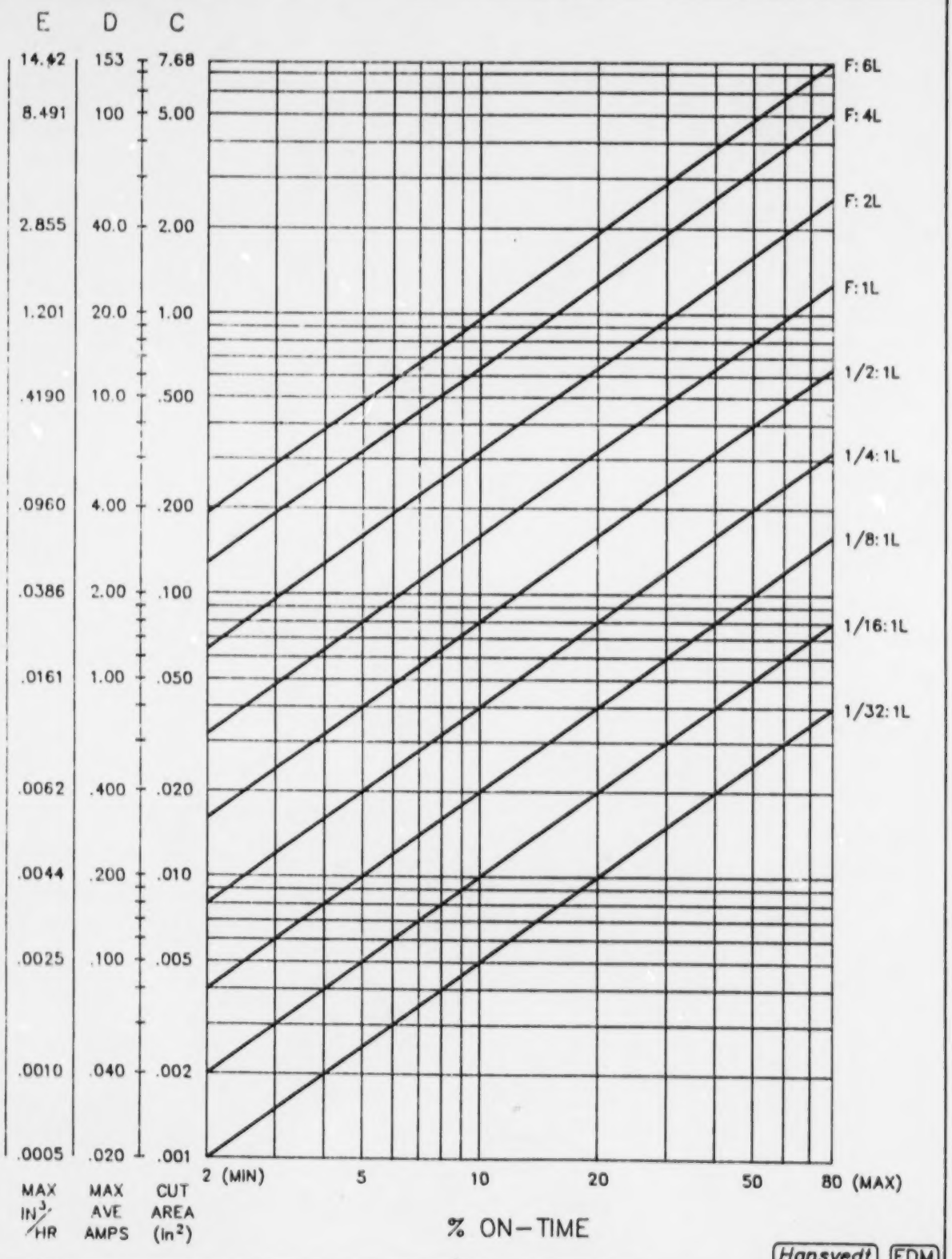
GRAPH A	OVERCUT	COPPER (+) / ALUMINUM (−)



GRAPH B	FINISH	COPPER (+) / ALUMINUM (−)



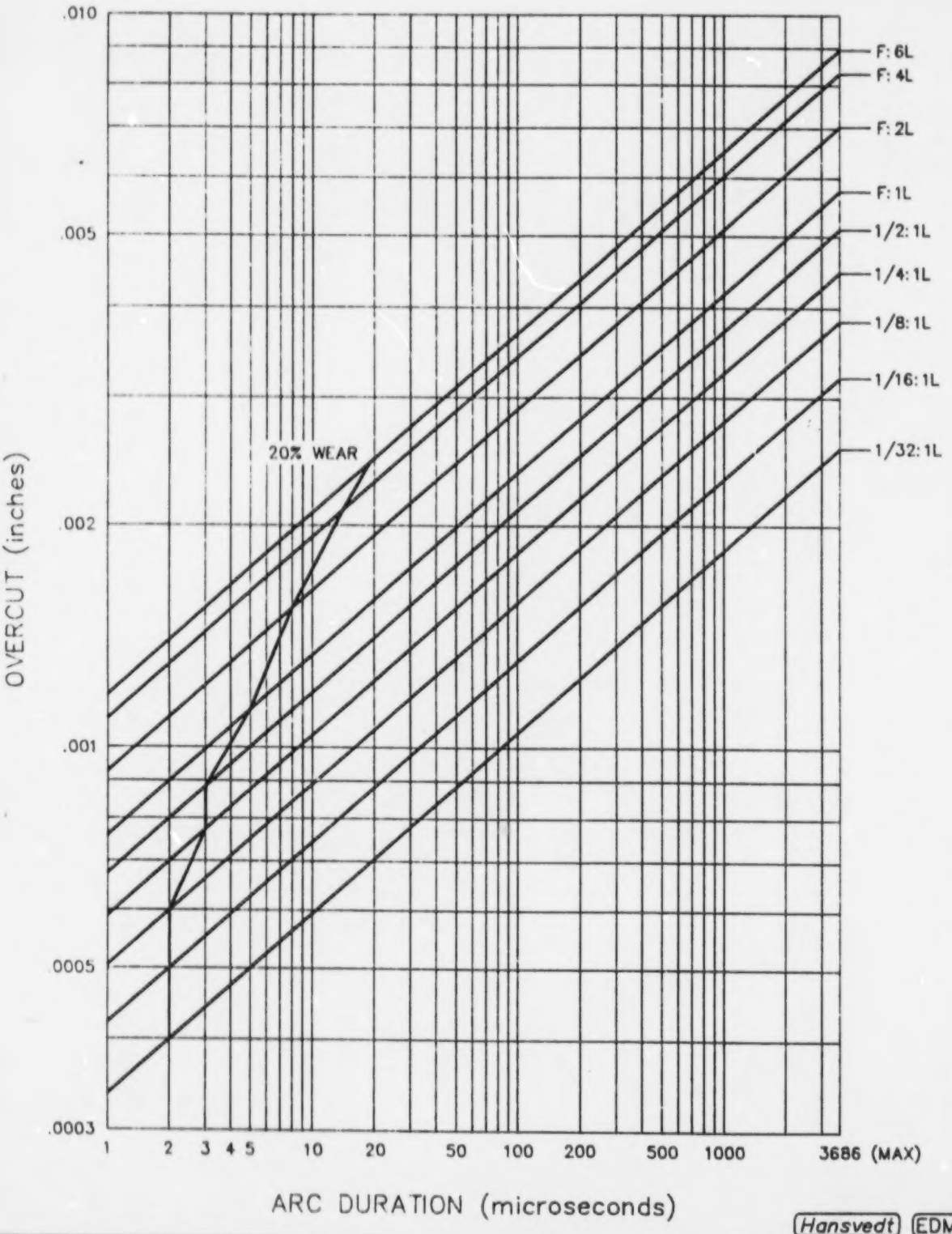
GRAPH C–E	CUTTING SPEED	COPPER (+) / ALUMINUM (–)



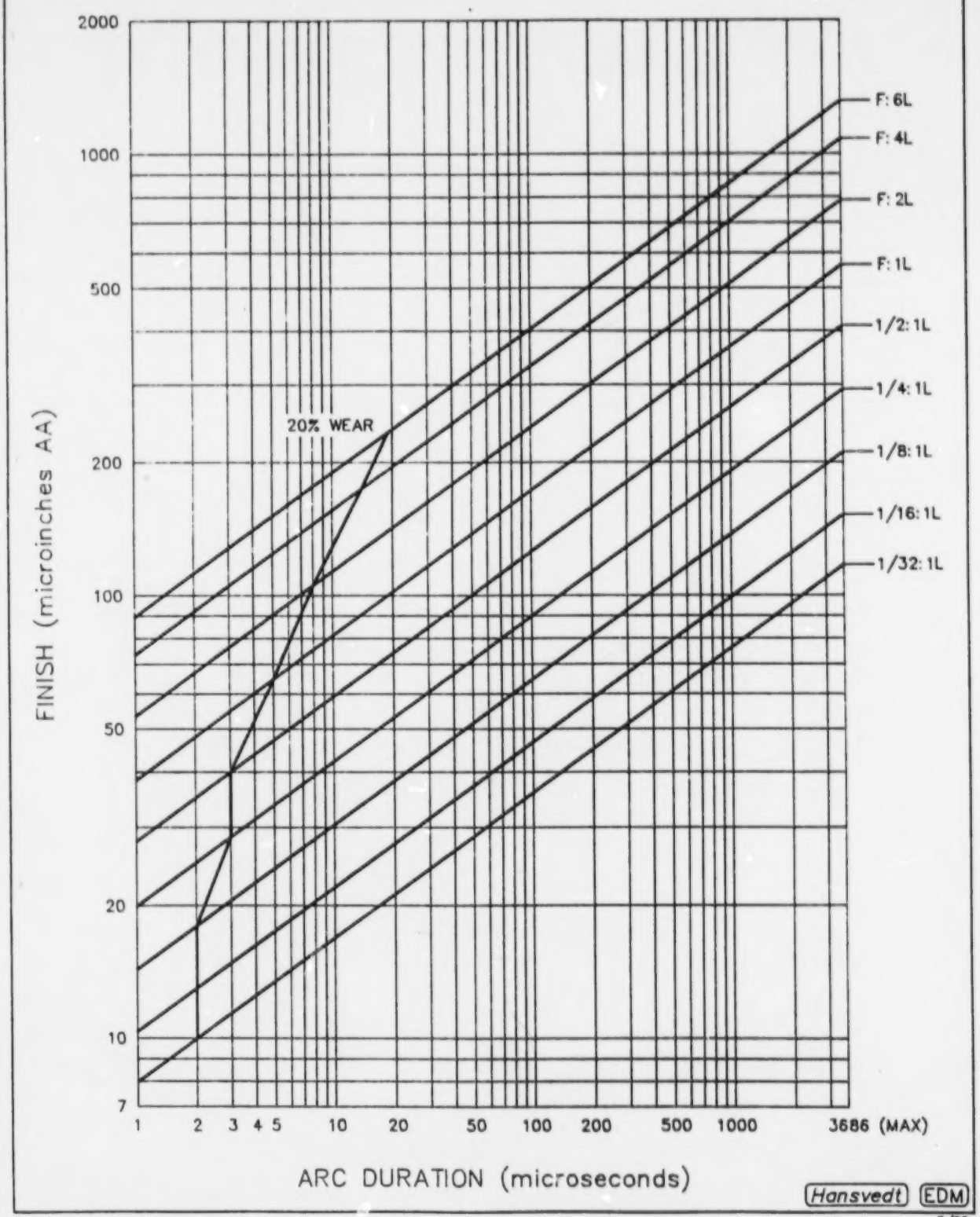
Hansvedt EDM

7/69

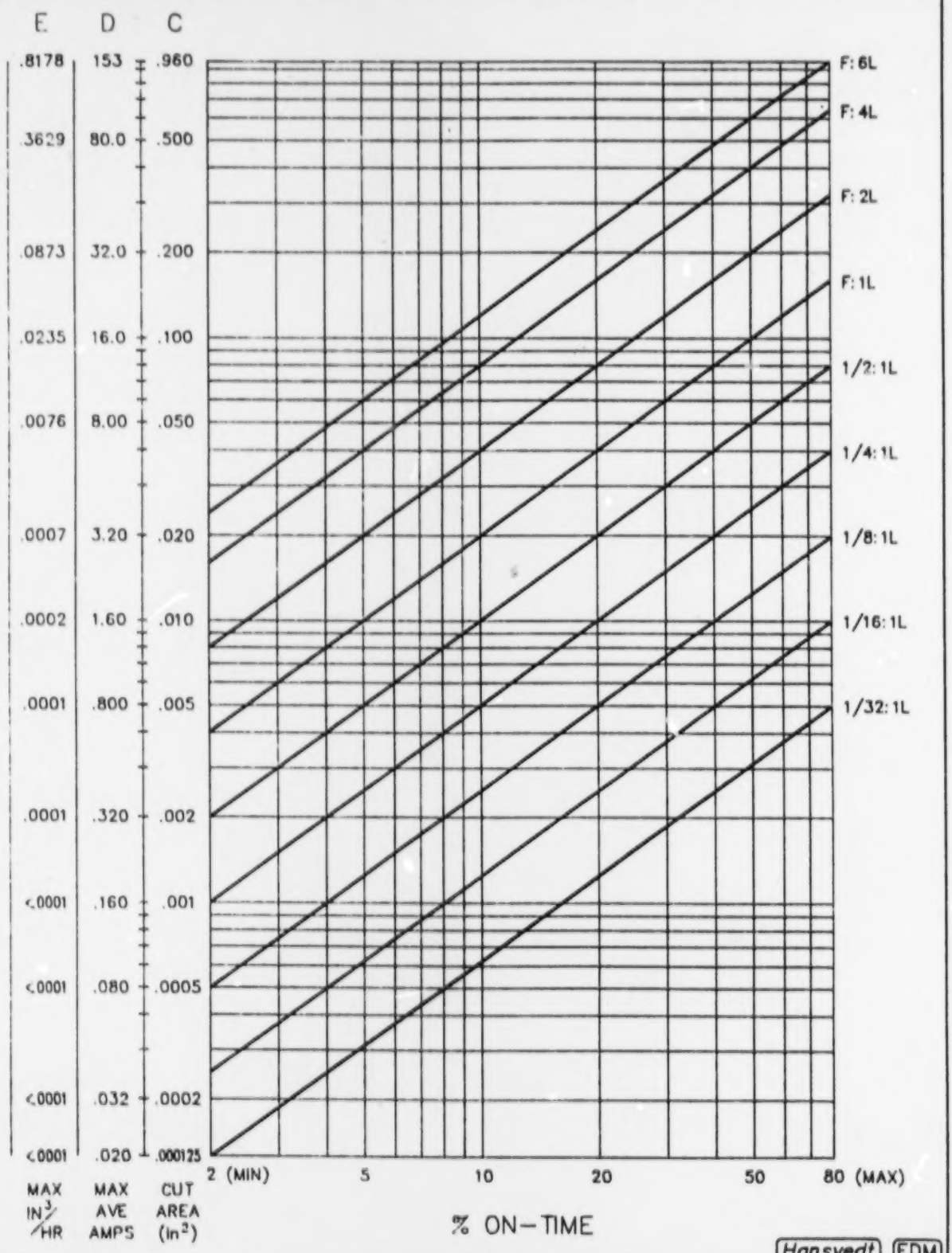
GRAPH A	OVERCUT	COPPER–TUNGSTEN (–) / CARBIDE (+)



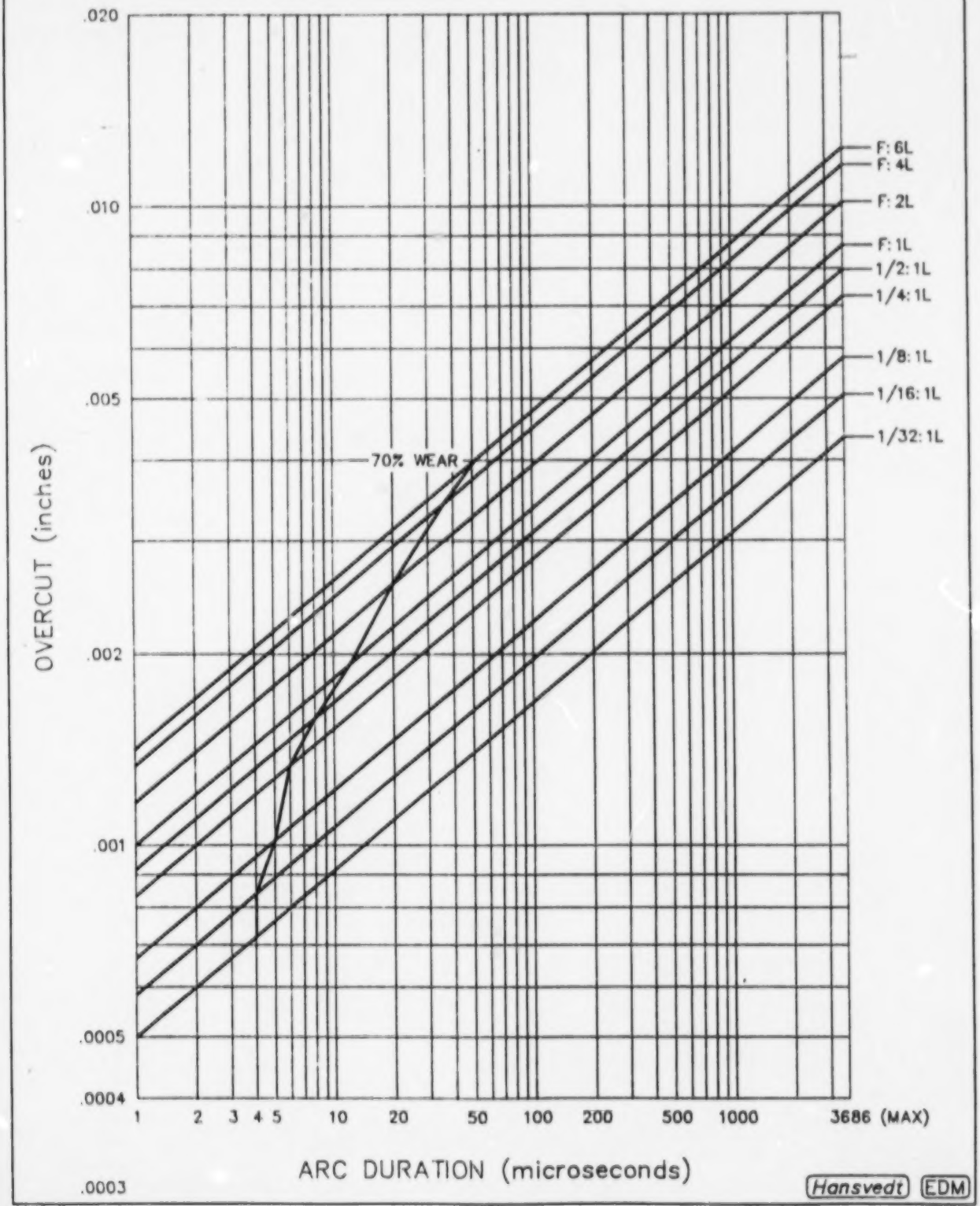
GRAPH B	FINISH	COPPER–TUNGSTEN (–) / CARBIDE (+)



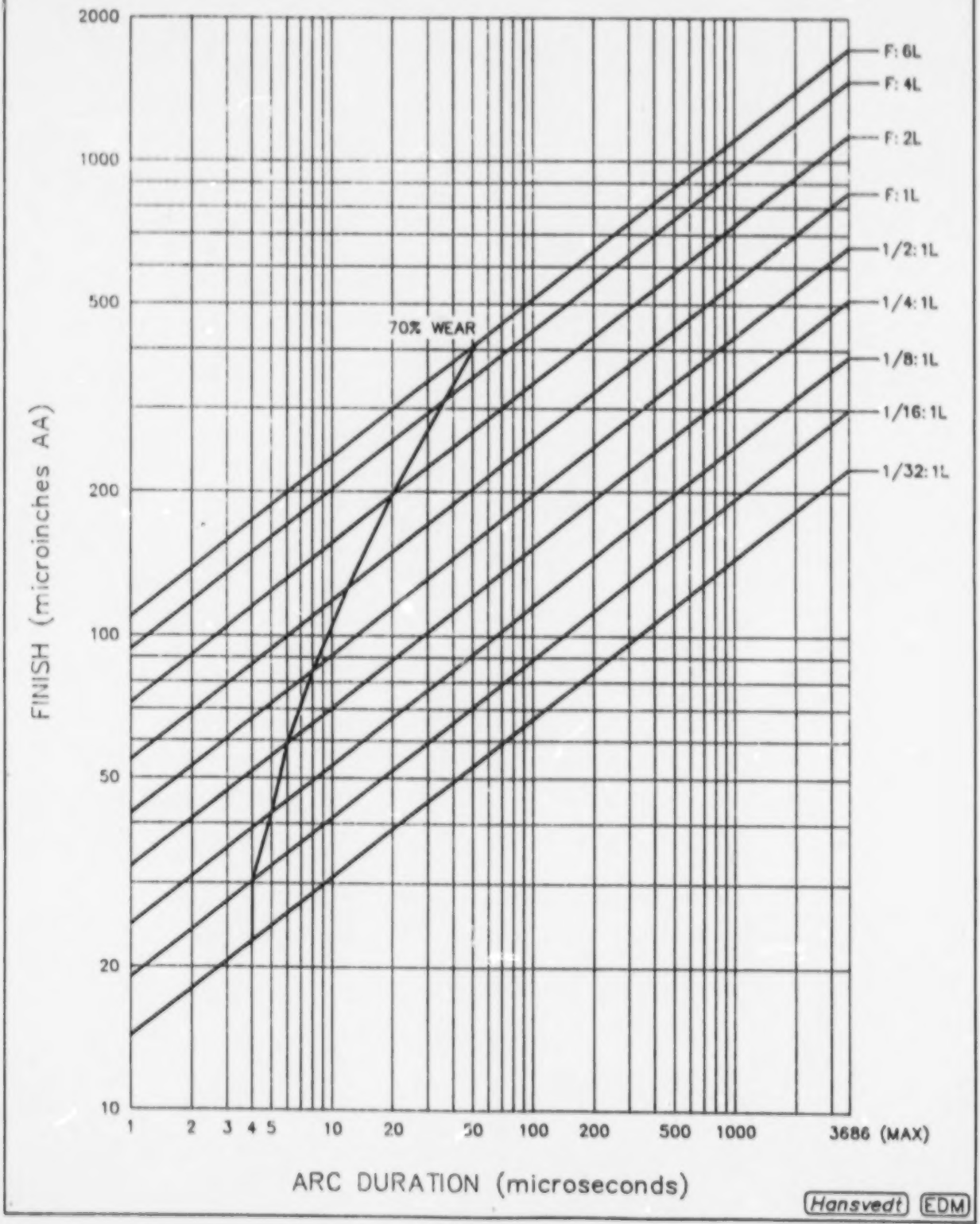
GRAPH C–E	CUTTING SPEED	COPPER–TUNGSTEN (–) / CARBIDE (+)



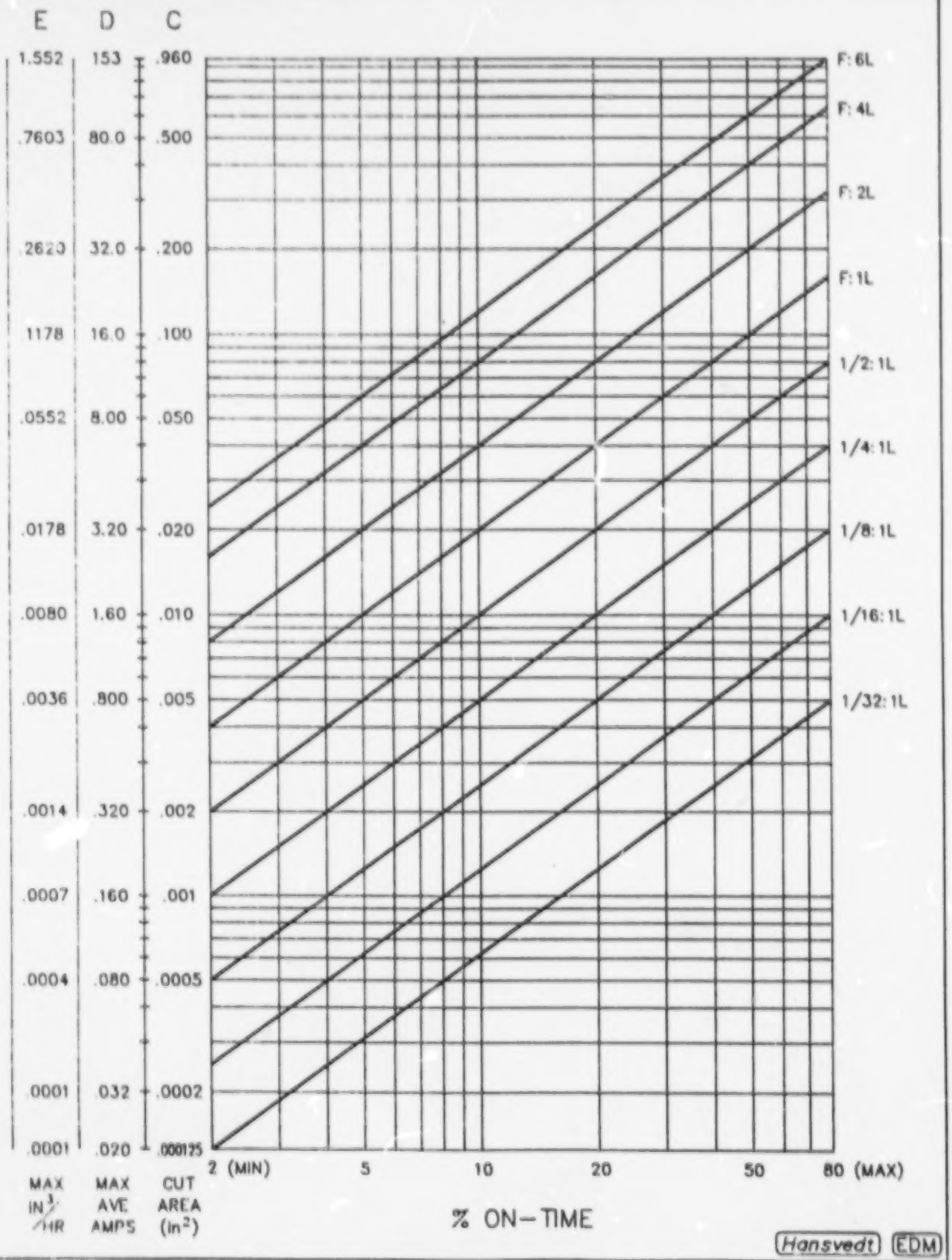
GRAPH A	OVERCUT	COPPER–GRAPHITE (–) / CARBIDE (+)



GRAPH B	FINISH	COPPER–GRAPHITE (–) / CARBIDE (+)



GRAPH C–E	CUTTING SPEED	COPPER–GRAPHITE (–) / CARBIDE (+)



Appendix 2

ARC DURATION MULTIPLIER CHART

Arc Durations

ARC DURATION	MULTIPLIER 1	1.2	1.4	1.6	1.8
.5	.5	.6	.7	.8	.9
1	1	1.2	1.4	1.6	1.8
2	2	2.4	2.8	3	3.6
4	4	4.8	5.6	6	7.2
8	8	9.6	11.2	12	14.4
16	16	19.2	22.4	24	28.8
32	37	38.4	44.8	48	57.6
64	64	76.8	89.6	96	115.2
128	128	153.6	179.8	192	230.4
256	256	307.2	358.4	384	460.8
512	512	614.4	716.8	768	921.6
1024	1024	1228.8	1433.6	1536	1843.2

This table will assist the EDM operator in determining the proper settings for the ARC DURATION and MULTIPLIER controls on the 201 power supply.

1. Find the arc duration from the bottom of one of the Electrode/Workpiece Combination Graphs A or B.

2. Look at Table H and find the number closest to this arc duration number.

3. Move vertically and horizontally from the value selected to the left side and top of Table H. The numbers arrived at will be the correct settings for the ARC DURATION and MULTIPLIER controls, respectively.

EXAMPLE: Find 25 μs on one of the Graphs A or B. Find the closest number (24) on Table H. Move to the left and find the Arc Duration setting (16). Move straight up to the top for the Multiplier setting (1.6).

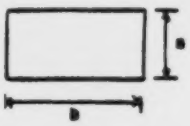
AREA FORMULAS

SQUARE

$A = s^2$

CIRCLE

$A = \pi r^2$

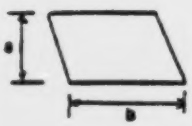


RECTANGLE

$A = ab$

CIRCLE SECTOR

$A = \frac{r\theta}{2}$

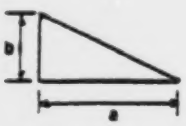


PARALLELOGRAM

$A = ab$

CIRCULAR RING

$A = \pi(R^2 - r^2)$

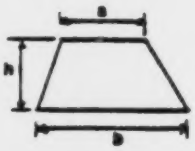


RIGHT TRIANGLE

$A = \frac{ab}{2}$

FILLET

$A = 0.215\, r^2$

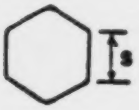


TRAPEZOID

$A = \frac{(a+b)\,h}{2}$

ELLIPSE

$A = \pi ab$



HEXAGON

$A = 2.598\, s^2$

Appendix 3

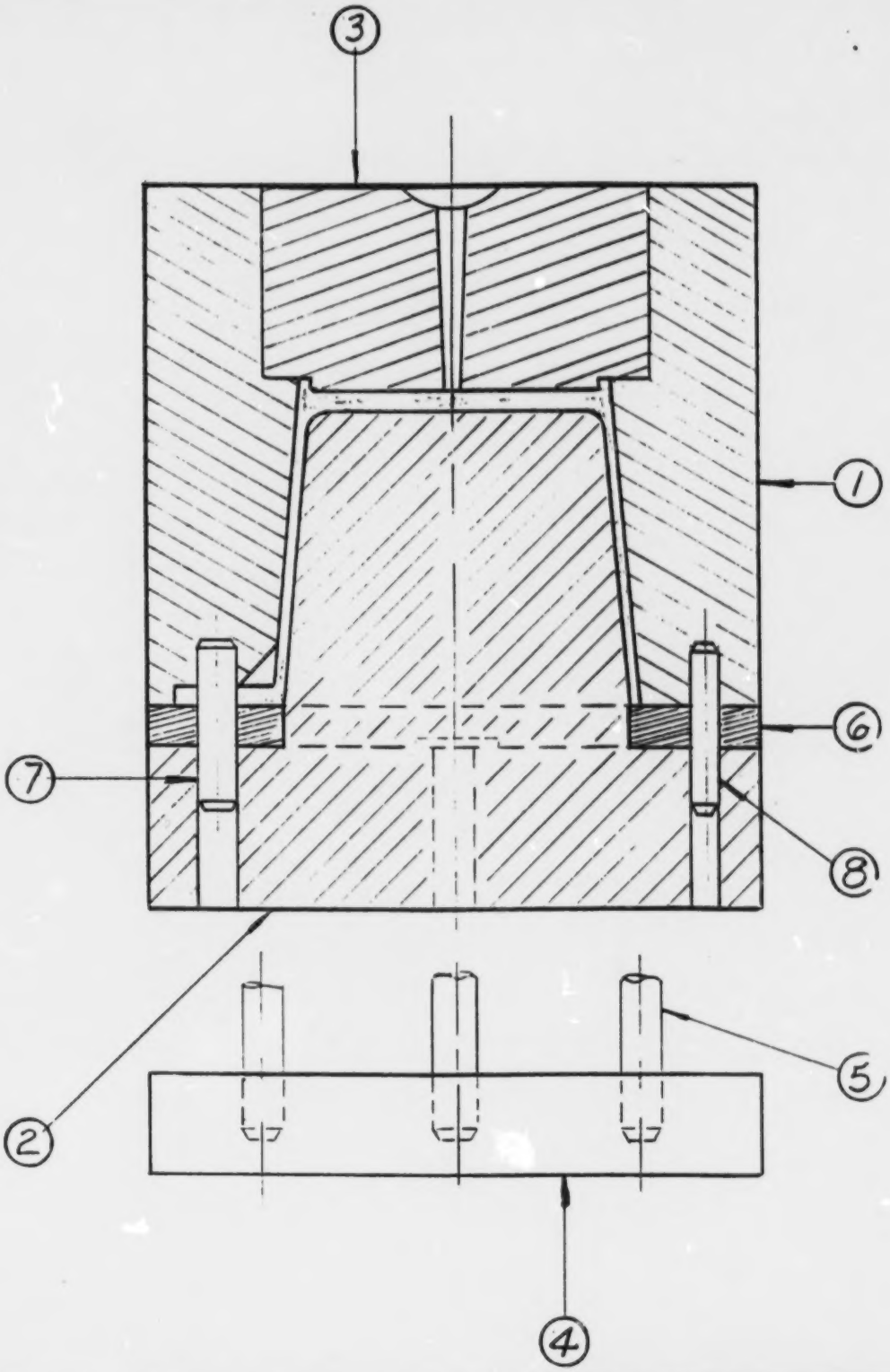
AREA FORMULAS

Appendix 4

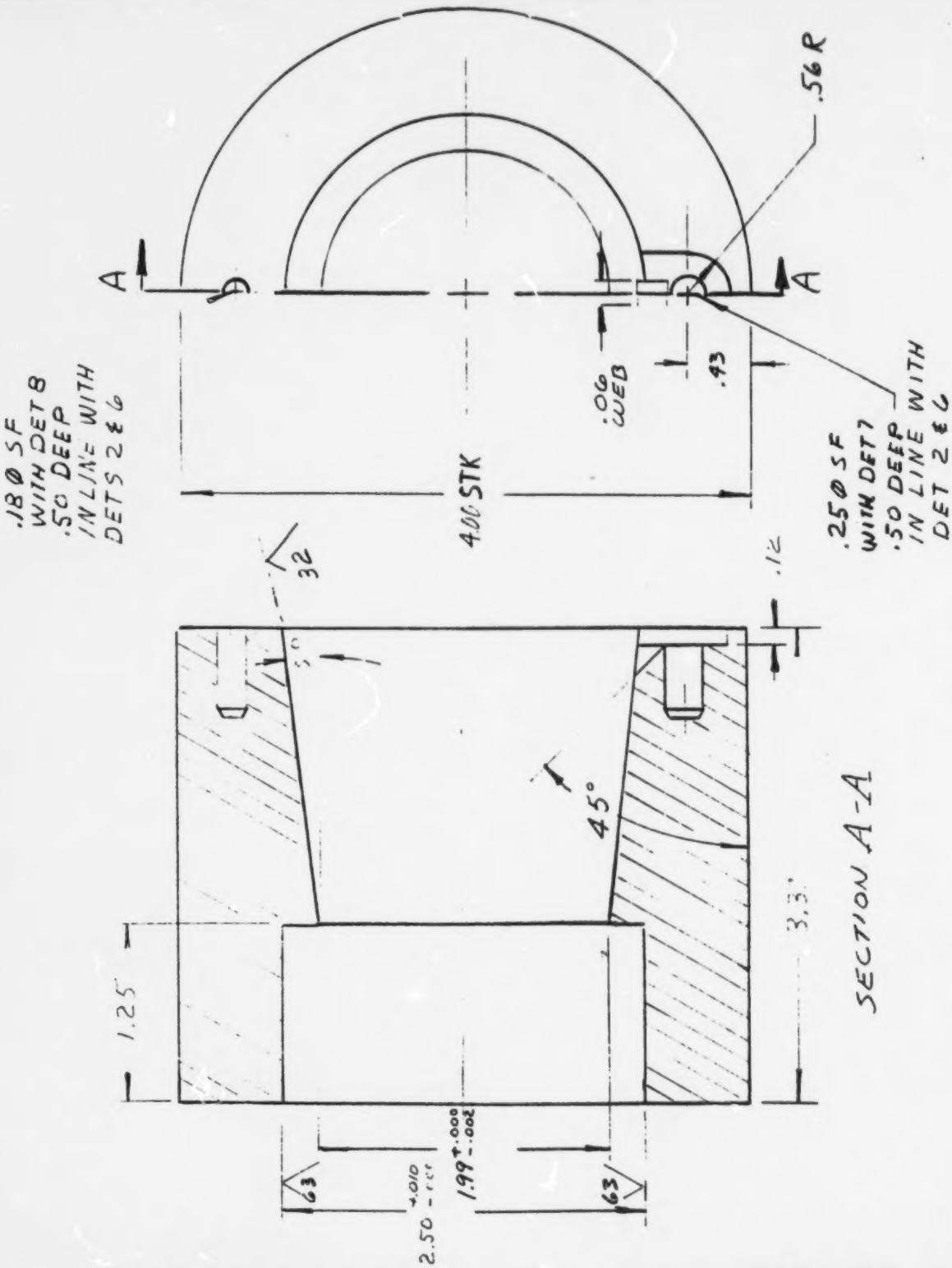
PROJECT PRINTS

ITEM	NO REQ	NAME	MATERIAL	SIZE
1	1	MOLD CAVITY	ALUMINUM	4.00 Ø STK X 3.50
2	1	BASE	"	4.00 Ø STK X 3.50
3	1	SPRUE INSERT	"	2.50 Ø X 1.25
4	1	EJECTOR PIN HOLDER	"	4.00 Ø STK X .62
5	3	DOWEL PINS	STEEL	1.62 X .25 Ø
6	1	EJECTOR RING	SAE 1018	4.00 Ø STK X .25
7	1	DOWEL PIN	STD	1.00 X .25 Ø
8	1	DOWEL PIN	STD	1.00 X .18 Ø

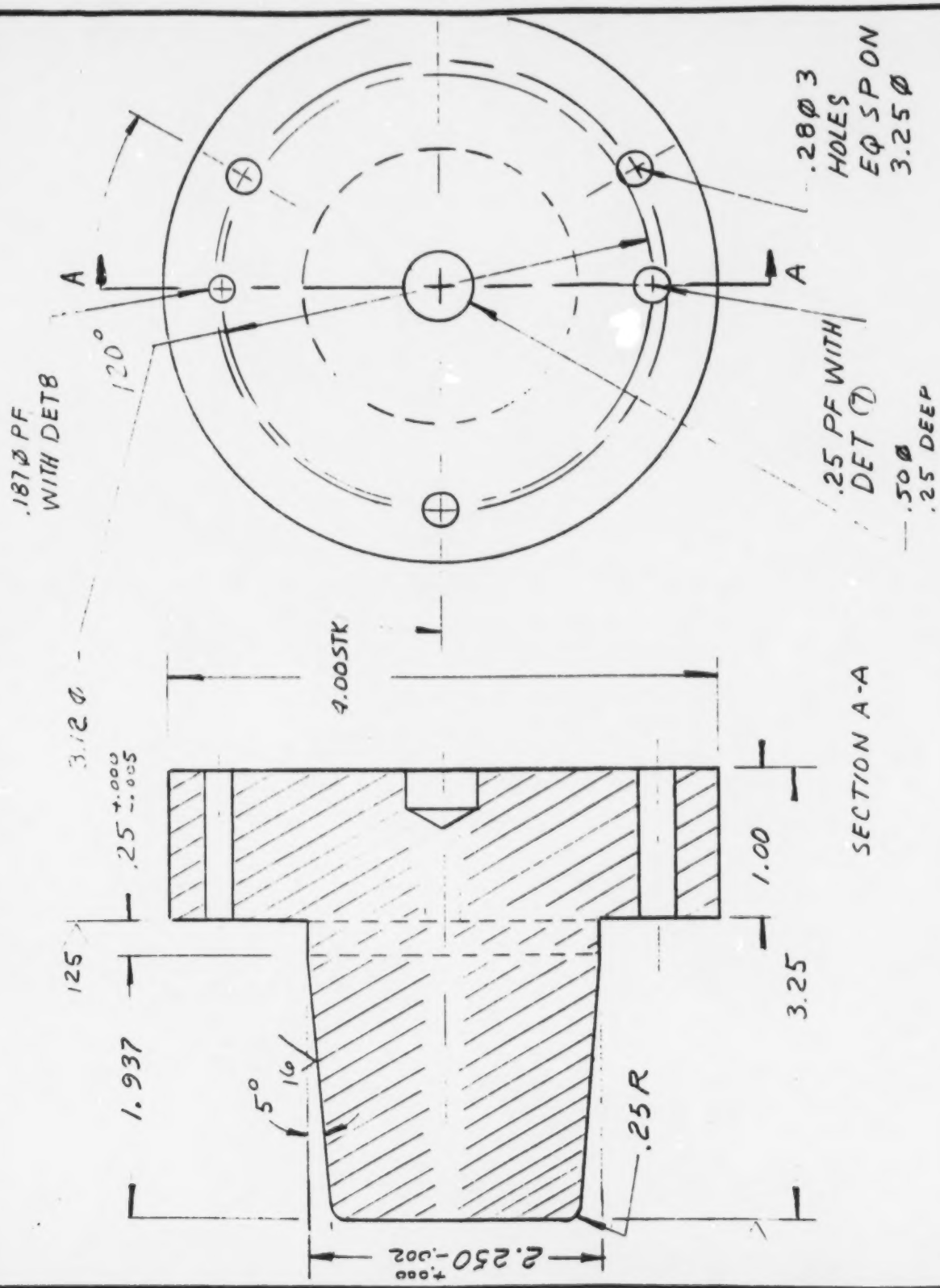
ANG ± ____ FRAC ± ____ XX ± ____ XXX ± ____ XXXX ± ____	MATL: ____ NO. REQ. ____ DET. NO. ____	TOOL AND DIE MAKING CUP MOLD Scale: / Sh 1 of 7



ANG ±	MATL:	TOOL AND DIE MAKING
FRAC ±	NO. REQ.	CUP MOLD
XX ±	DET. NO.	
XXX ±		Scale: FULL — Sh. 2 of 7
XXXX ±		



ANG ± 1/2°	MATL: ALUM	TOOL AND DIE MAKING	
FRAC ± .01	NO. REQ. 1	MOLD CAVITY	
XX ± .02	DET. NO. 1	Scale: FULL	Sh 3 of 7
XXX ± .005			
XXXX ± .0005			



ANG ± ½°	MATL: ALUM	TOOL AND DIE MAKING	
FRAC ± .01	NO. REQ. 1	BASE	
XX ± .02	DET. NO. 2	Scale: FULL	Sh 4 of 7
XXX ± .005			
XXXX ± .0005			

ANG ± 1/2°
FRAC ± .01
XX ± .02
XXX ± .005
XXXX ± .0005

MATL: ALUM
NO. REQ. 1
DET. NO. 3

160

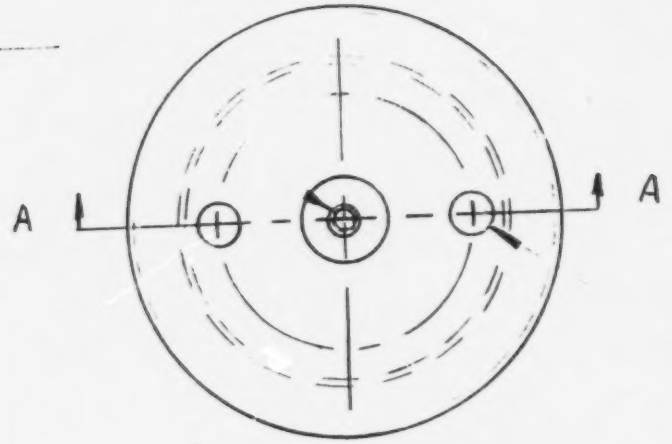
TOOL AND DIE MAKING

SPRUE INSERT

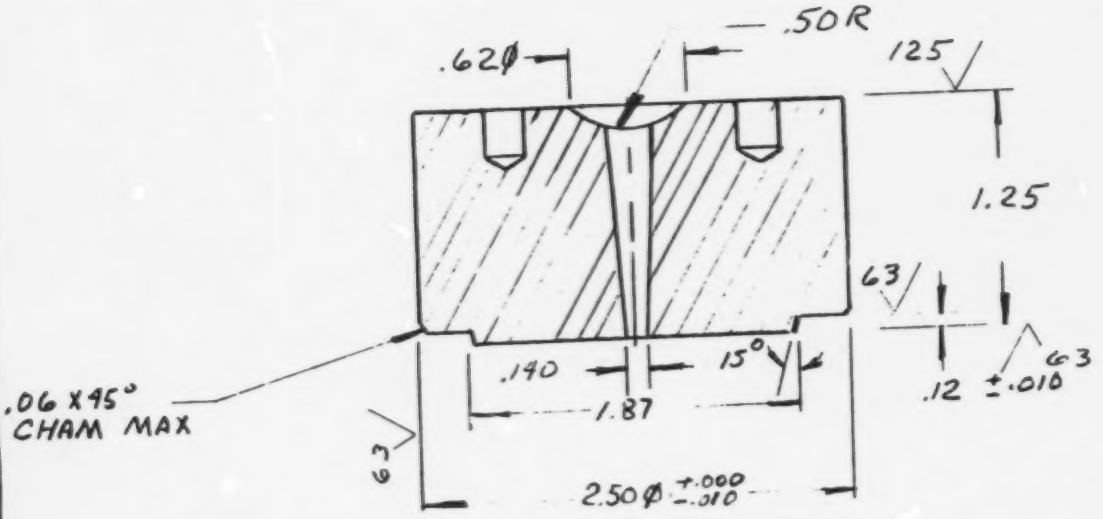
Scale: FULL

Sh 5 of 7

.50 TPF
SPRUE REAMER



.25 Ø DRILL X .25 DEEP
2 PLACES ON 1.50 Ø

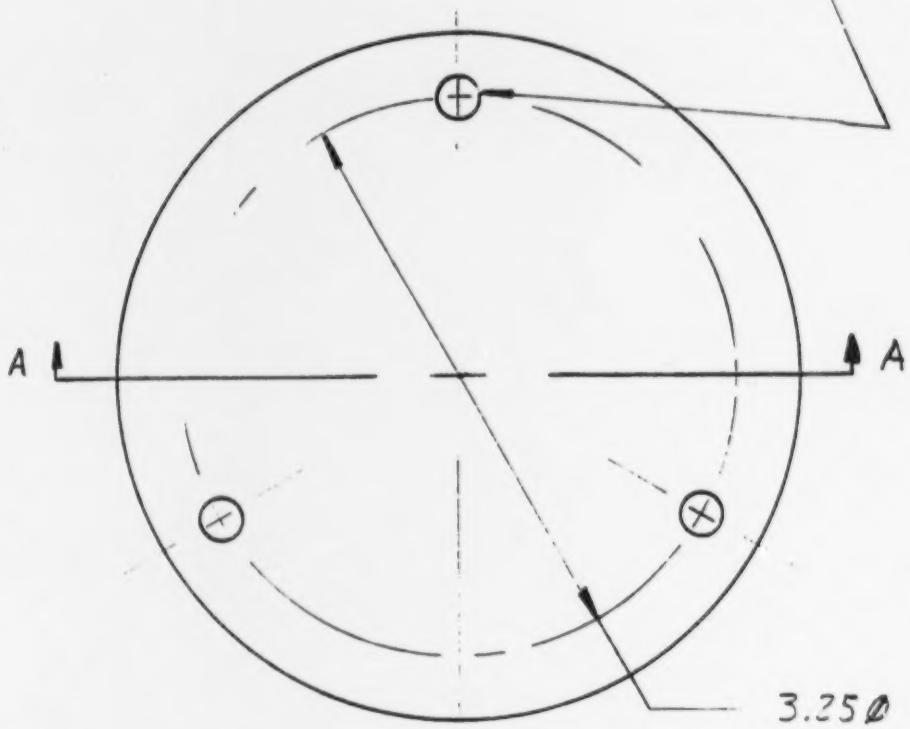


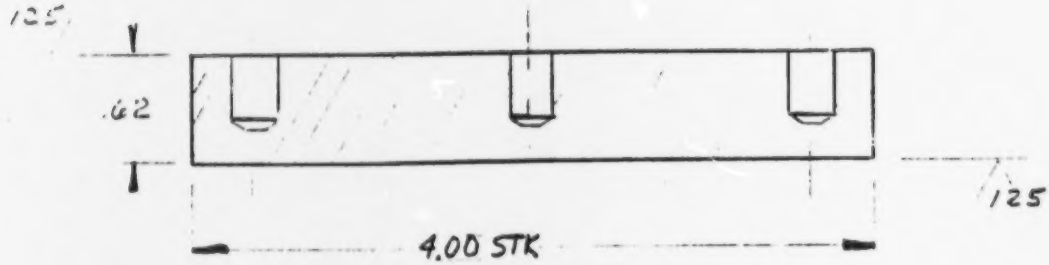
SECTION A-A

.25 Ø PF WITH DET ⑤ IN LINE WITH DET ②

NOTE

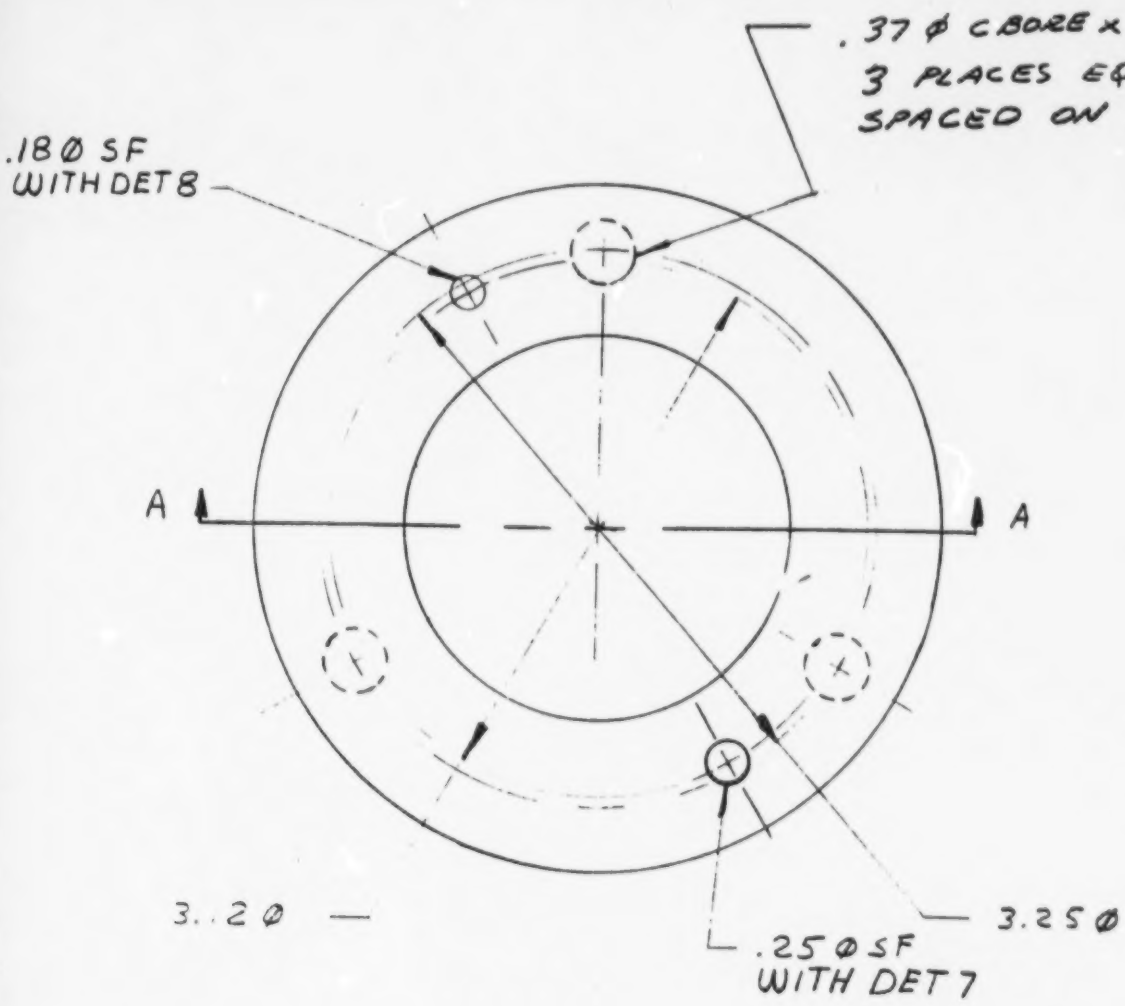
1 REMOVE ALL SHARP EDGES .03 MAX

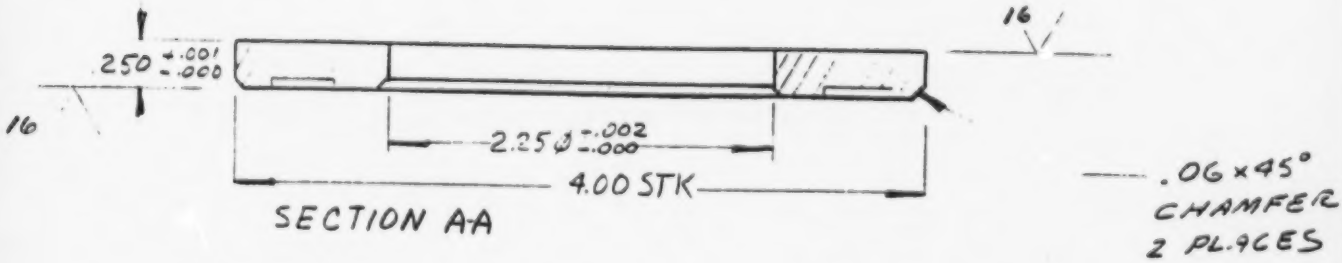




SECTION A-A

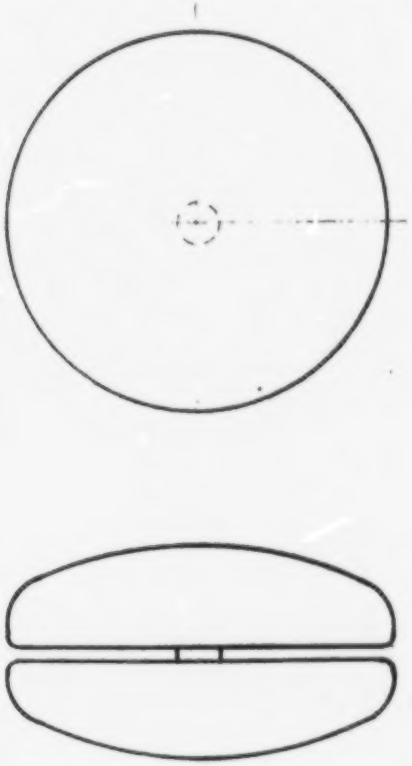
ANG ± 1°	MATL: 1018	TOOL AND DIE MAKING	
FRAC ± .01	NO. REQ. 1	EJECTOR PIN HOLDER	
XX ± .02	DET. NO. 4	Scale: FULL	Sh 6 of 7
XXX ± .005			
XXXX ± .0025			



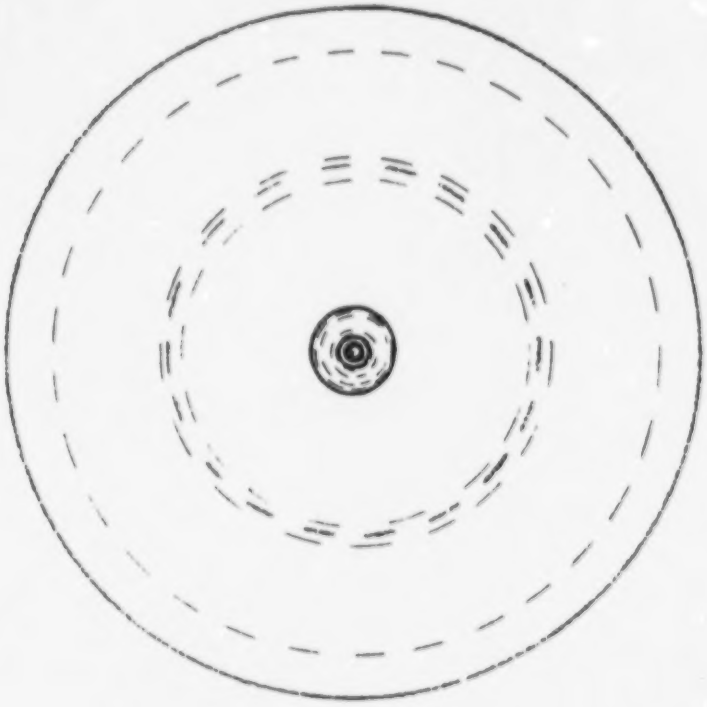


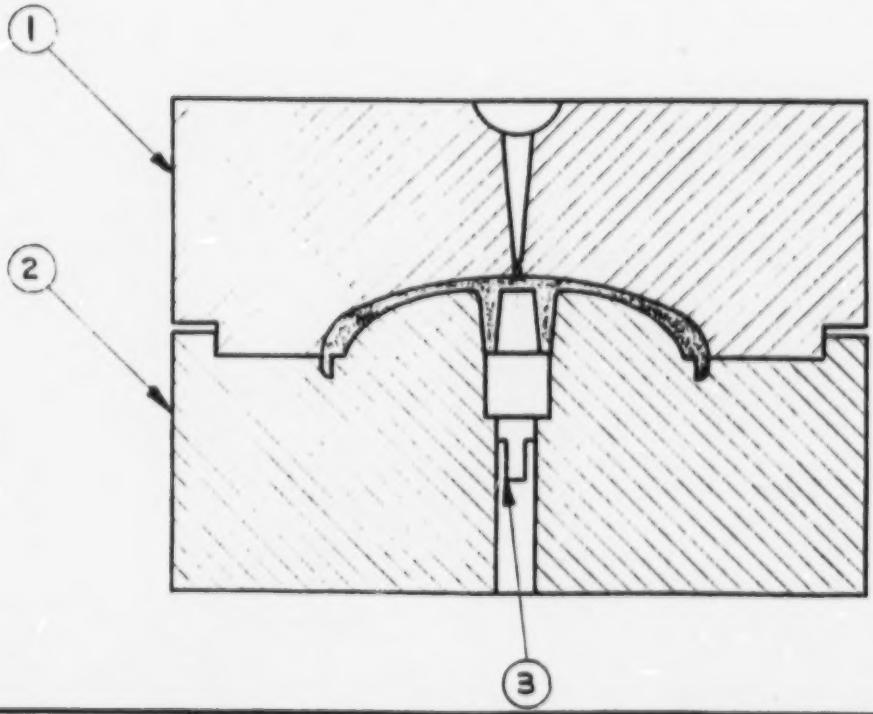
SECTION A-A

ANG ± 1°	MATL: 1018	TOOL AND DIE MAKING	
FRAC ± .01	NO. REQ. 1	EJECTOR RING	
XX ± .02	DET. NO. 6		
XXX ± .005		Scale: FULL	Sh 7 of 7
XXXX ± .0005	162		

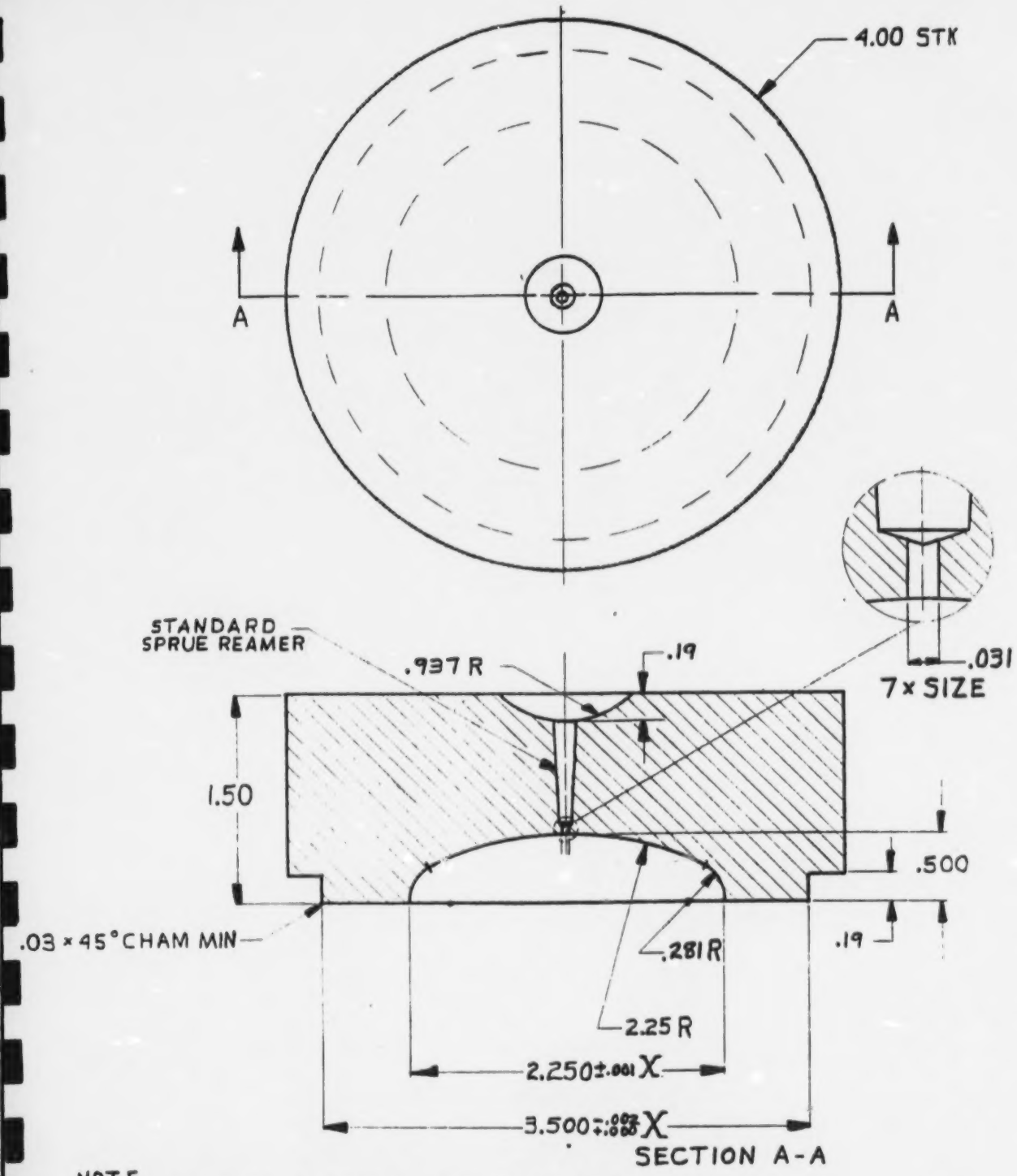


ANG ±		MATL:	TOOL AND DIE MAKING
FRAC ±		NO. REQ.	YO· YO
XX ±		DET. NO.	
XXX ±			Scale: FULL — Sh 1 of 6
XXXX ±			



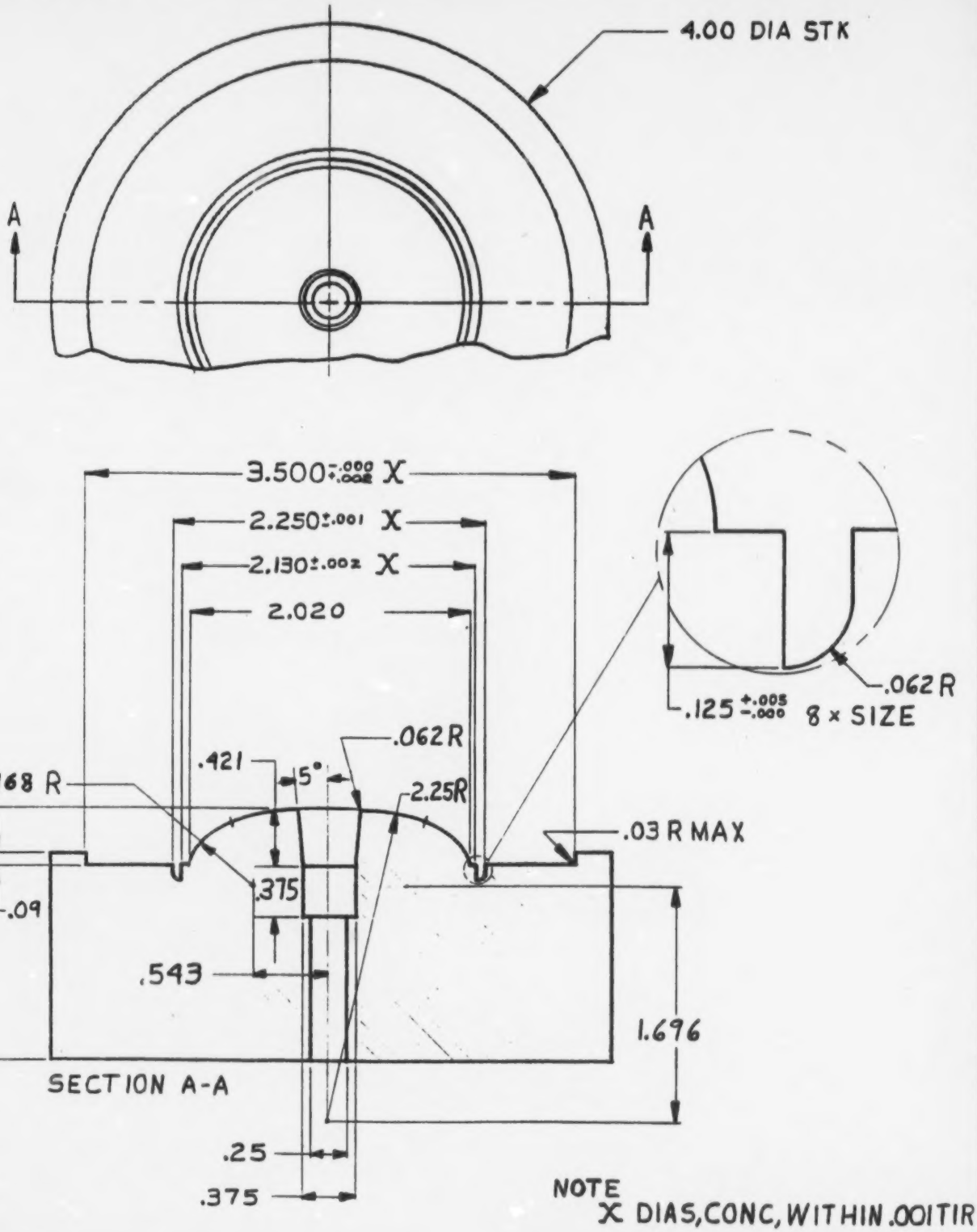


ANG ± ____ FRAC ± ____ XX ± ____ XXX ± ____ XXXX ± ____	MATL: ____ NO. REQ. ____ DET. NO. ASSY	TOOL AND DIE MAKING YO YO MOLD Scale: FULL — Sh 2 of 6

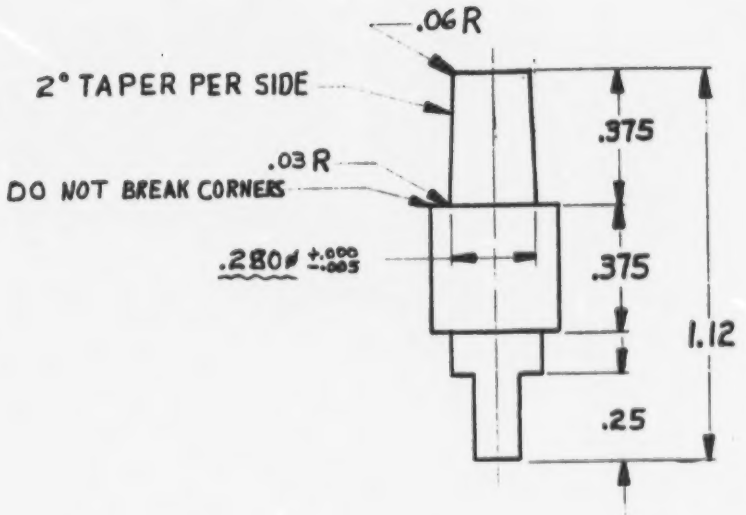


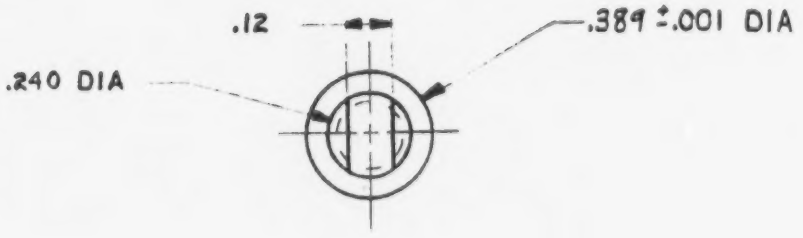
NOTE X DIAS TO BE CONC WITHIN .001 TIR

ANG ± 0°30'	MATL: ALUM	TOOL AND DIE MAKING	
FRAC ± 1/64	NO. REQ. 1	YO YO MOLD	
XX ± .02	DET. NO. 1		
XXX ± .005	165	Scale: FULL	Sh 3 of 6
XXXX ± .0005			

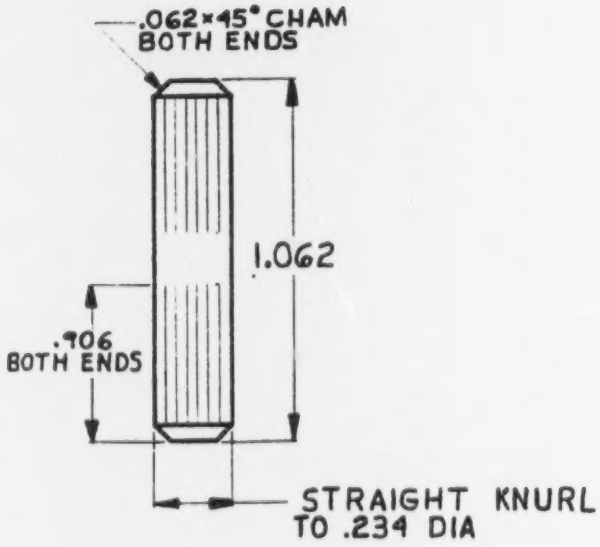


ANG ± 0° 30'	MATL: ALUM	TOOL AND DIE MAKING	
FRAC ± 1/64	NO. REQ. 1	YO YO MOLD	
XX ± .02	DET. NO. 2		
XXX ± .005		Scale: FULL	Sh 4 of 6
XXXX ± .0005			

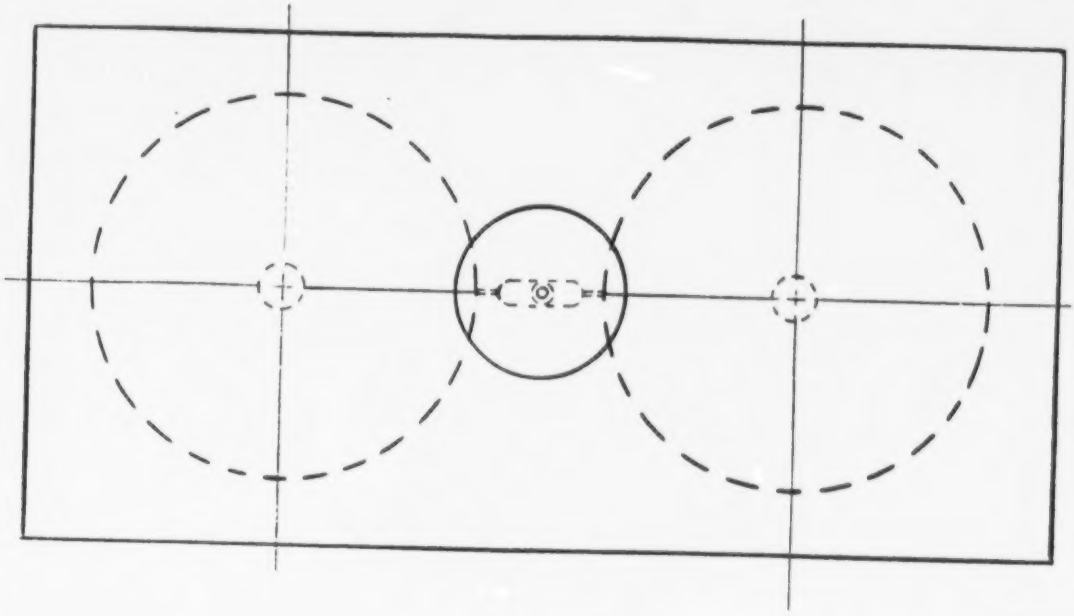


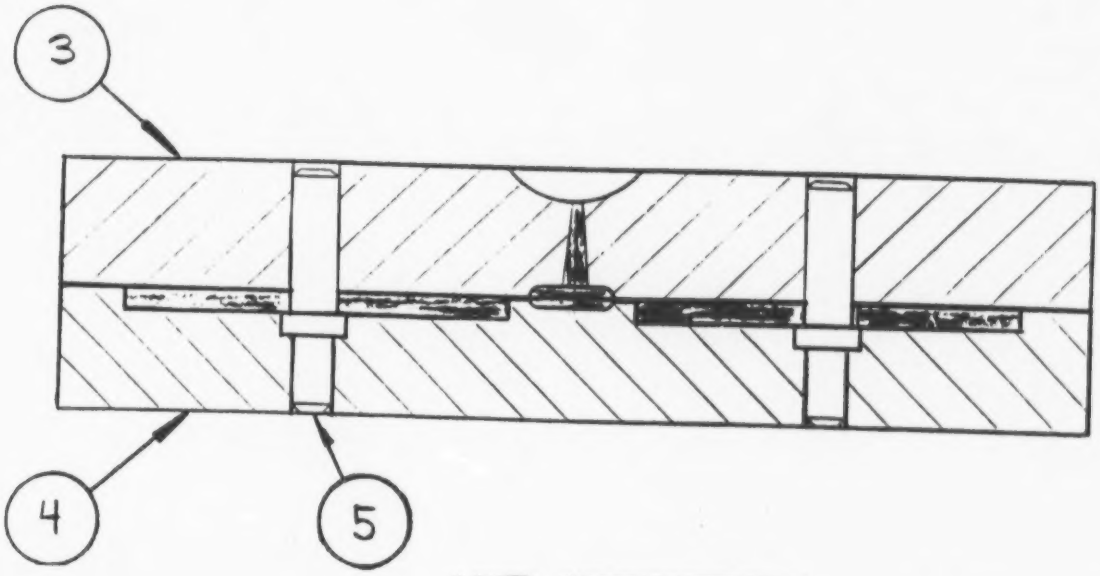


ANG ± 0°30'	MATL: M5	TOOL AND DIE MAKING	
FRAC ± 1/64	NO. REQ. 1	YO YO MOLD	
XX ± .02	DET. NO. 3		
XXX ± .005		Scale: 2× SIZE	Sh 5 of 6
XXXX ± .0005			

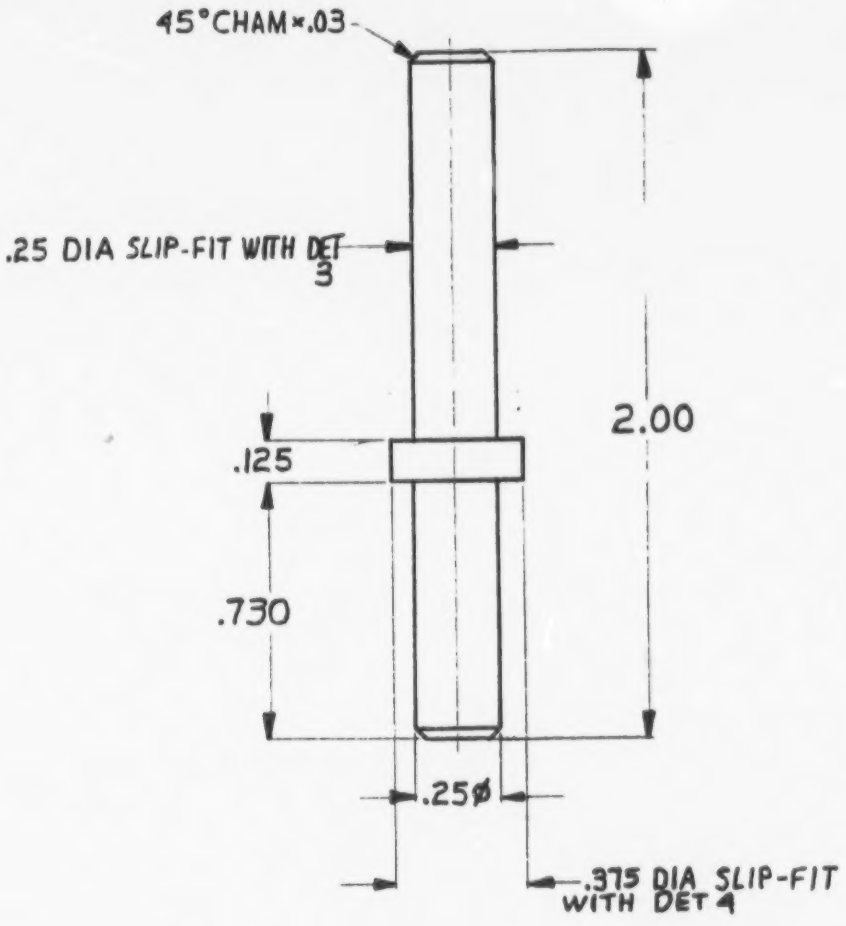


ANG ± 0°30'	MATL: MS	TOOL AND DIE MAKING	
FRAC ± 1/64	NO. REQ. 1	YO YO MOLD	
XX ±	DET. NO. —	STRING ARBOR (AXLE)	
XXX ± .005	168	Scale: 2×SIZE	Sh 6 of 6
XXXX ± .0005			

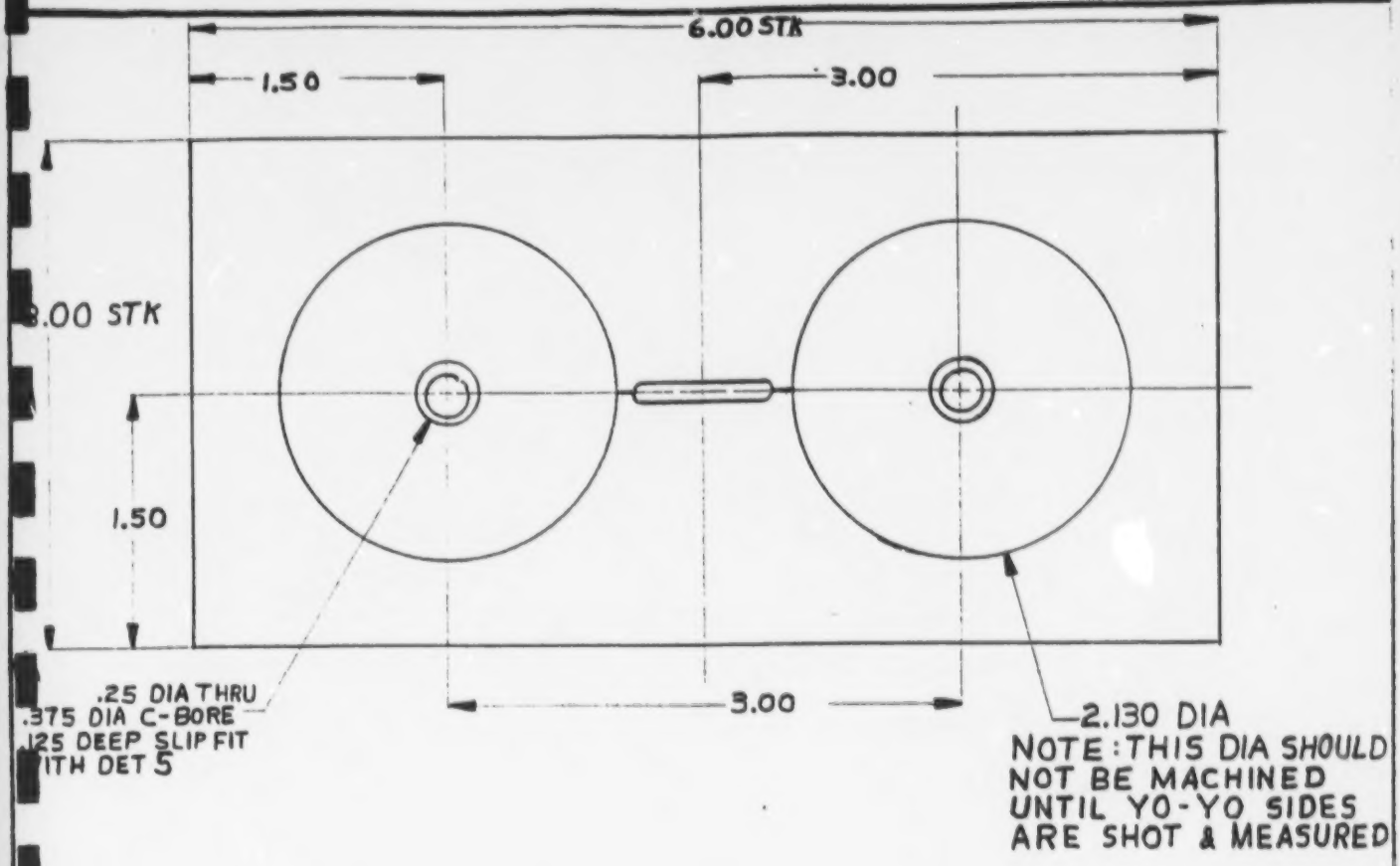


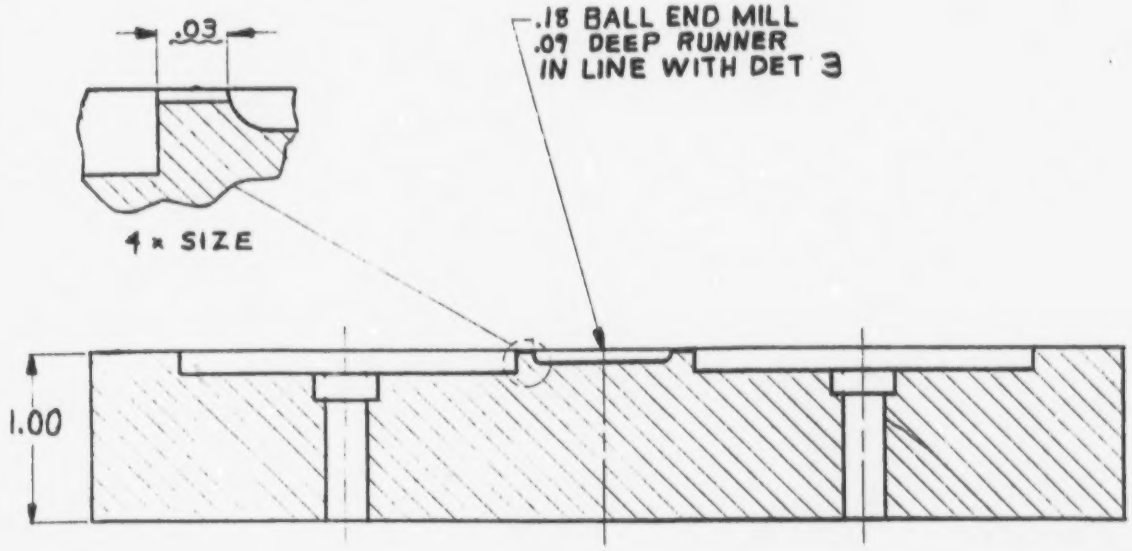


ANG ± ____ FRAC ± ____ XX ± ____ XXX ± ____ XXXX ± ____	MATL: ____ NO. REQ. ____ DET. NO. ____ 169	TOOL AND DIE MAKING YO YO MOLD STRING GUIDES	
		Scale: FULL	Sh 1 of 4

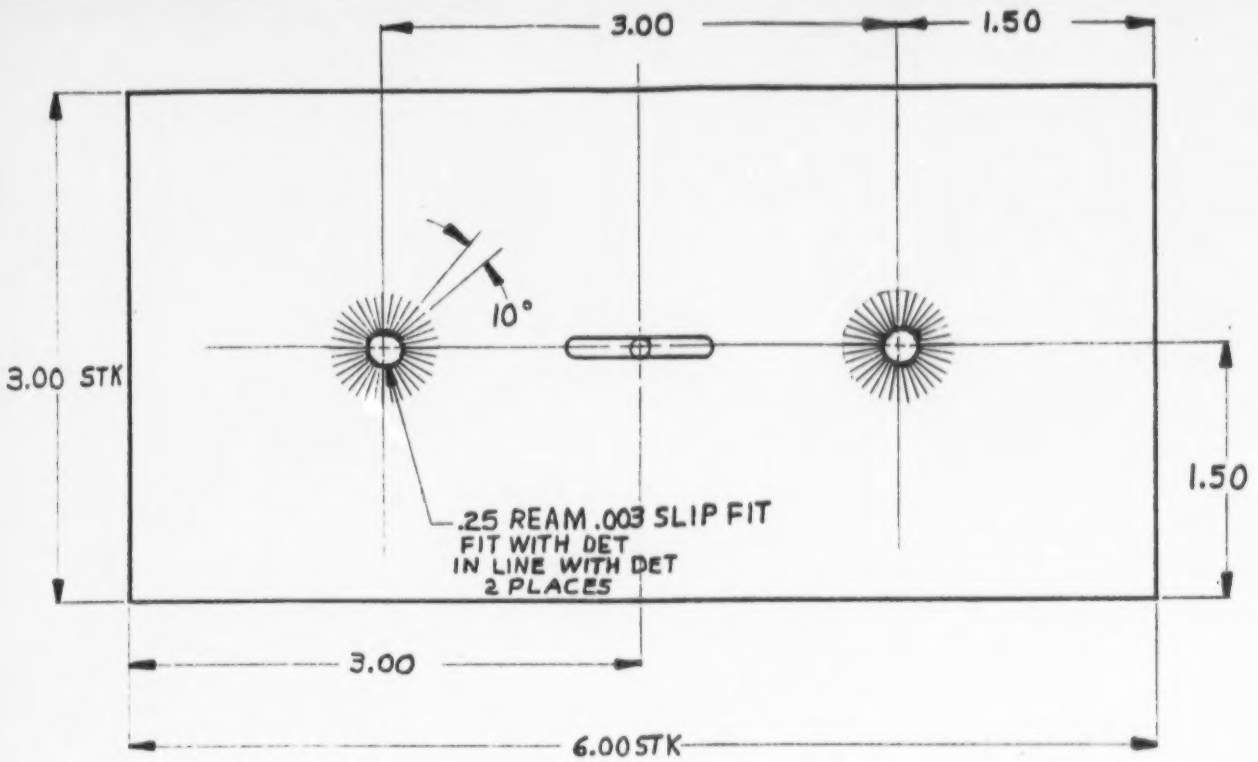


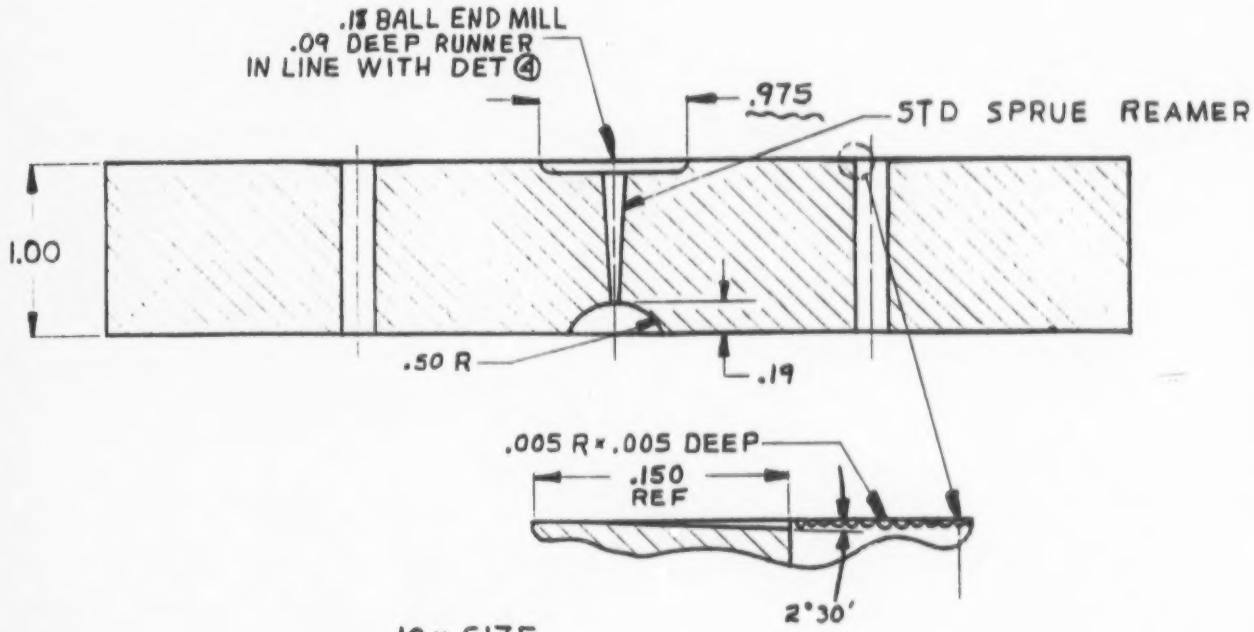
ANG ± 0° 30'	MATL: STEEL	TOOL AND DIE MAKING	
FRAC ± 1/64	NO. REQ.	YO YO MOLD STRING GUIDE	
XX ±	DET. NO. 5		
XXX ± .005		Scale: 2 x SIZE	Sh 2 of 4
XXXX ± .0005	170		





ANG ± 0° 30'	MATL: ALUM	TOOL AND DIE MAKING	
FRAC ± 1/64	NO. REQ. 1	YO YO MOLD	
XX ±	DET. NO. 9	STRING GUIDE	
XXX ± .005		Scale: FULL	Sh 3 of 4
XXXX ± .0005			





10 × SIZE

ANG ± 0°30'	MATL: ALUM	TOOL AND DIE MAKING	
FRAC ± 1/64	NO. REQ. —	YO YO MOLD	
XX ±	DET. NO. 3	STRING GUIDE	
XXX ± .005		Scale: FULL	Sh 4 of 4
XXXX ± .0005			

NO.	NAME	QU	SIZE	MATERIAL
3	MOLD TOP	1	4 DIA x 1.25	ALUMINUM
4	CENTER MOLD	1	4 DIA x 2	ALUMINUM
5	RING	1	4 DIA x .38	ALUMINUM
6	MOLD BASE	1	4 DIA x 1	ALUMINUM
7	TEE HEAD	8	.38 x .50	ALUMINUM
8	SPRUE EJECTOR	1	.25 DIA x 1.38	STEEL
9	DOWELL PINS	4	.25 DIA x 1.25	ALUMINUM

TOLERANCES
ANGULAR ±0° 30'
FRAC. ±1/64
.XXX ±.005
.XXX ±.0005

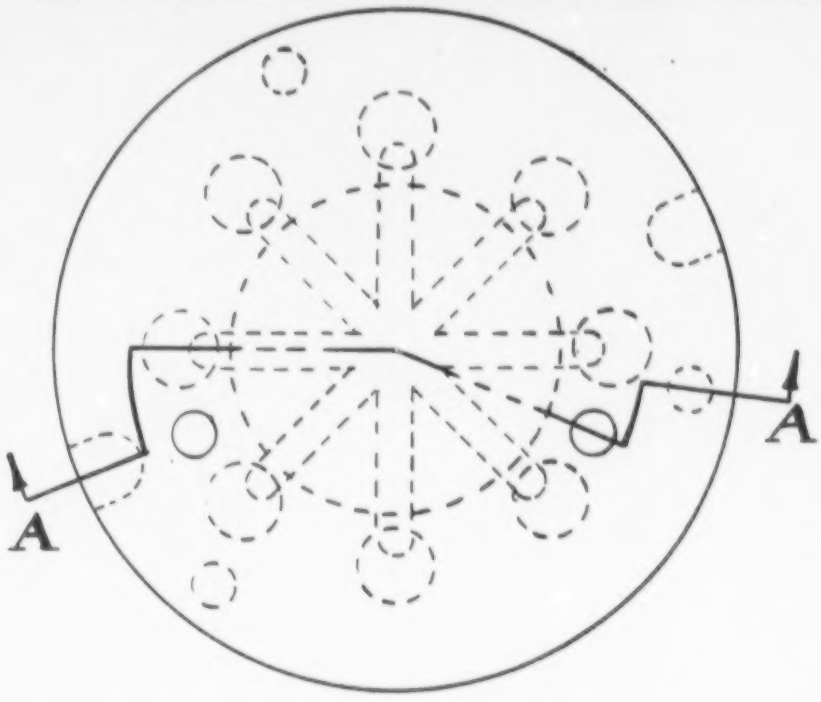
GOLF TEE MOLD

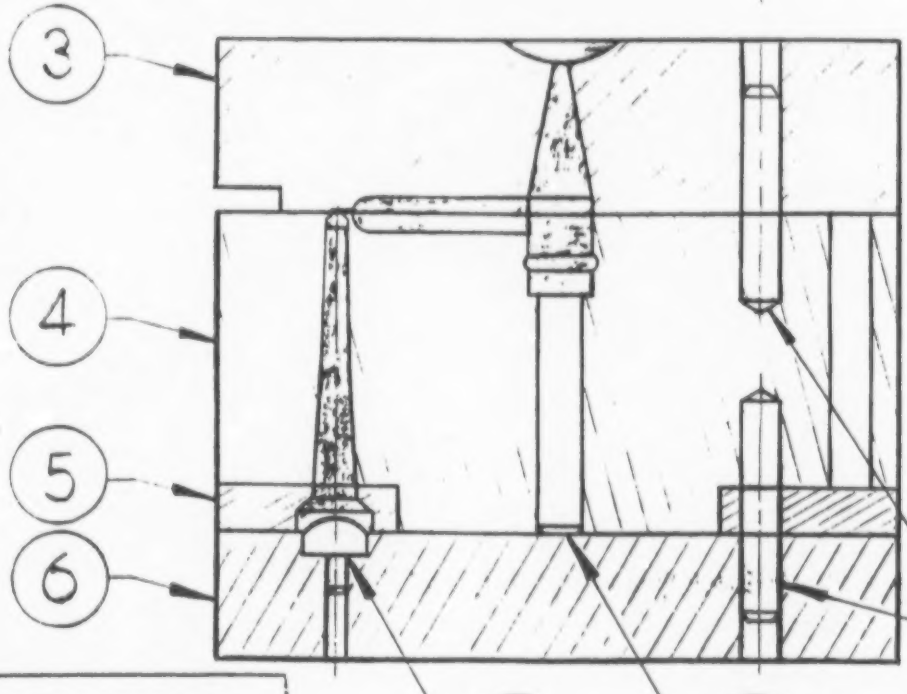
SHEETS 1 OF 7

COURSE TOOL + DIE

SCALE 173

MAT'L. REQ. 1



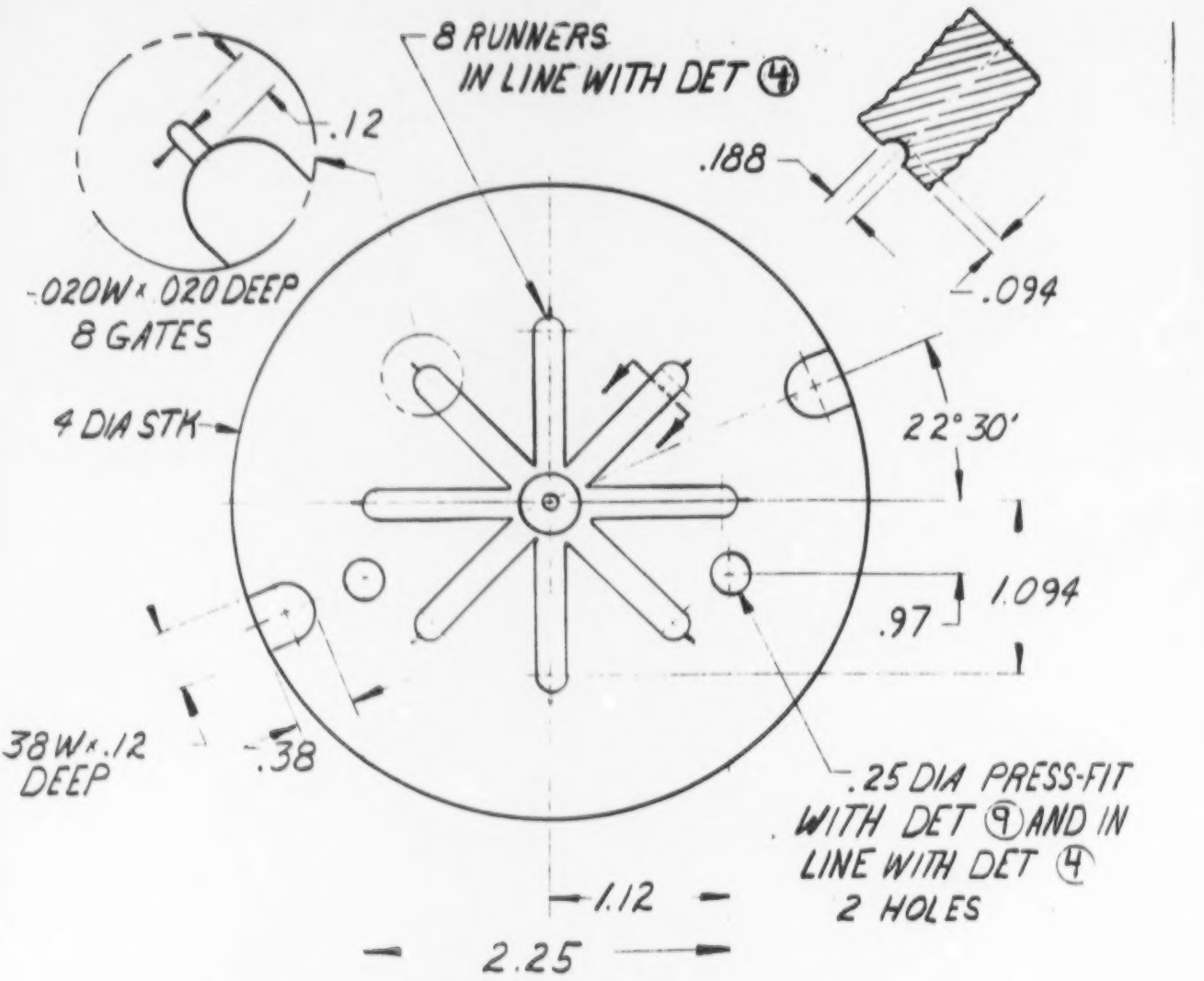


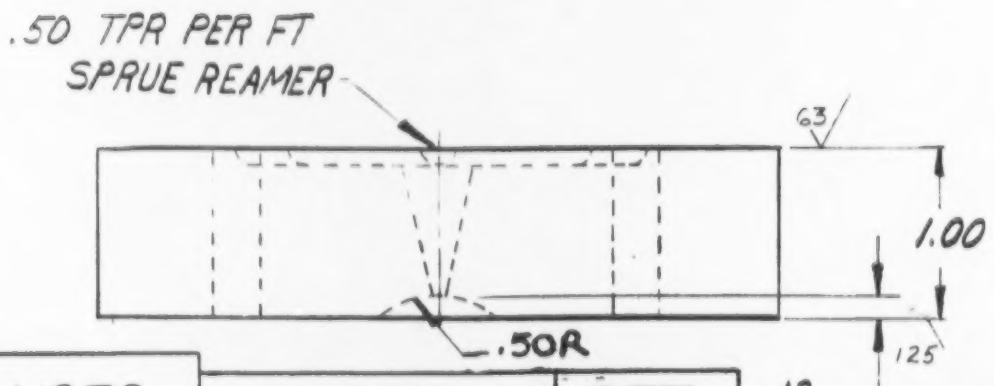
SECTION A-A

SHEET 2 OF 7

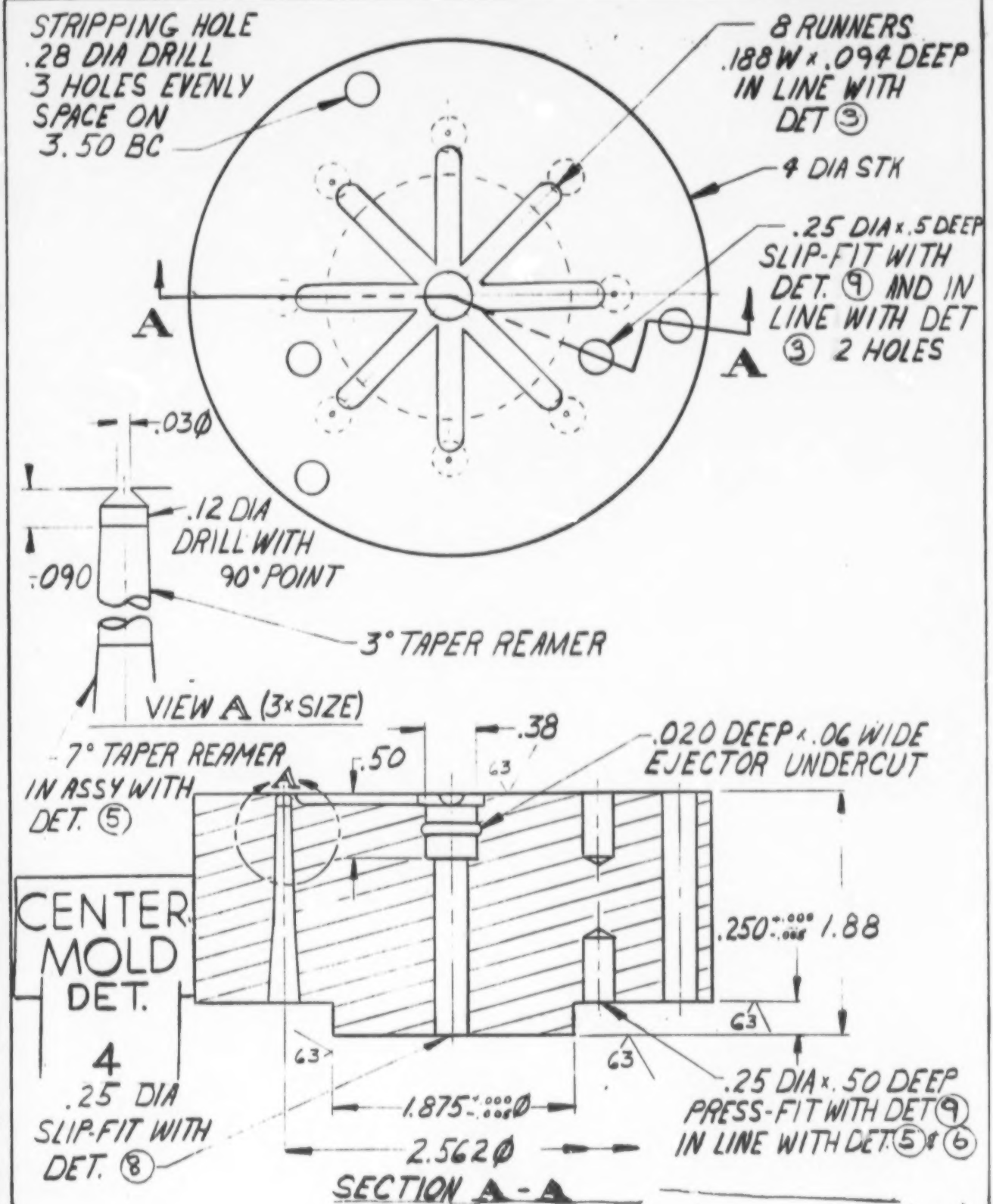
ASSEMBLY

TOLERANCES	COURSE	SCALE	MAT'L AL
ANGULAR ±0° 30'	TOOL + DIE	FULL	REQ. 1
FRAC. ±1/64			
.XXX ±.005			
XXXX ±.0005			



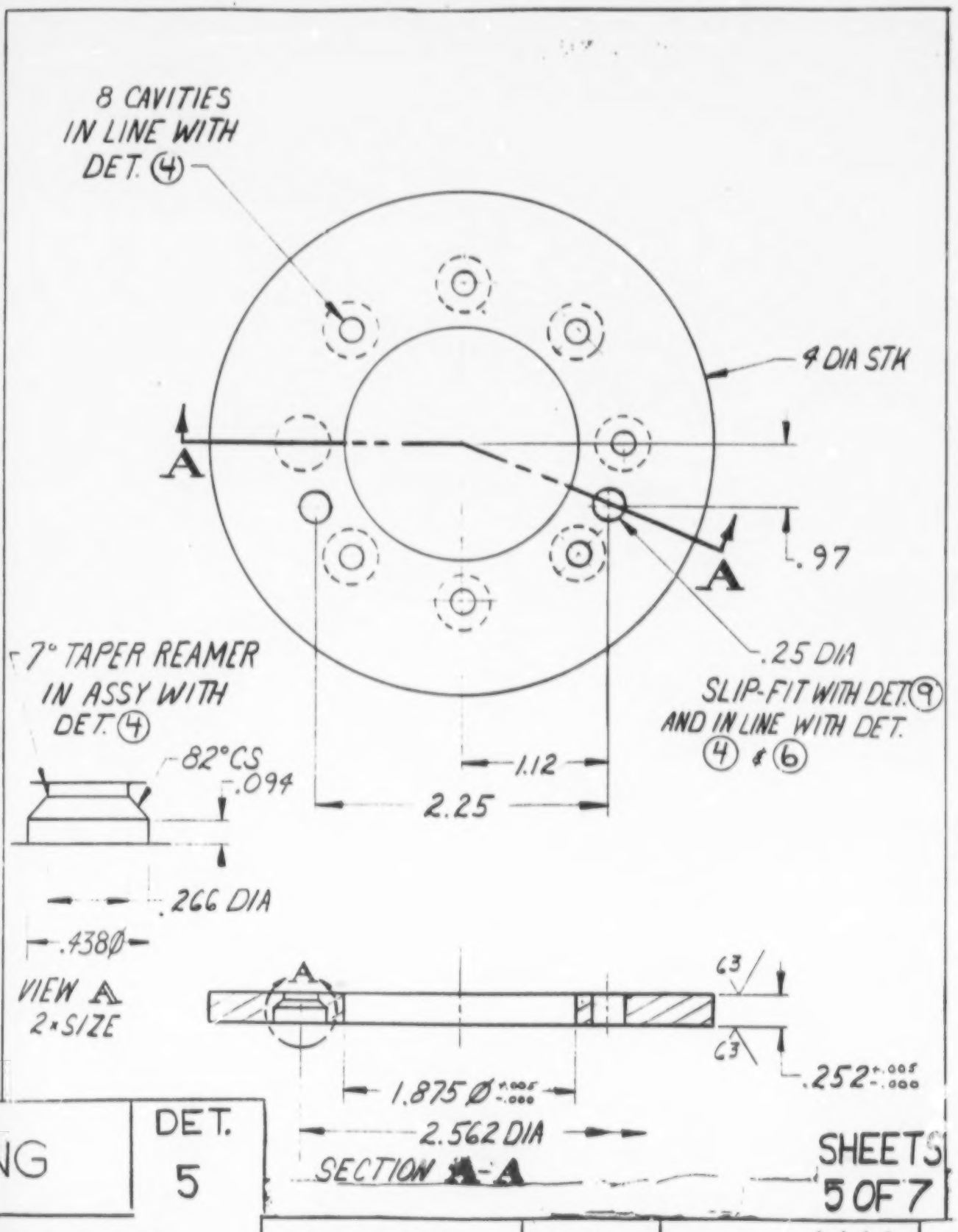


TOLERANCES ANGULAR ±0° 30' FRAC. ±1/64 .XXX ±.005 .XXXX ±.0005	MOLD TOP	DET. 3	SHEETS 3 OF 7
	COURSE TOOL + DIE	SCALE FIII.	MAT'L ALU. REQ. 1

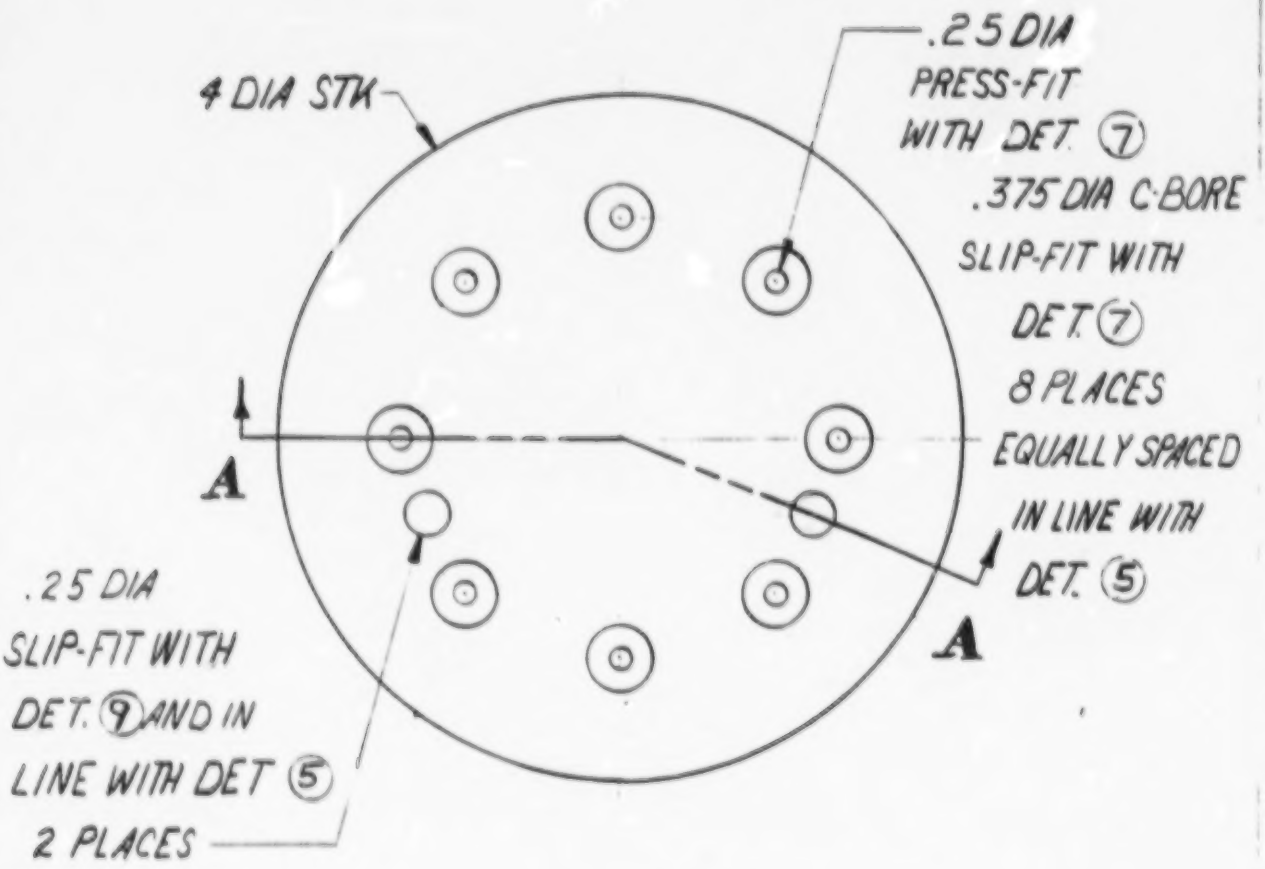


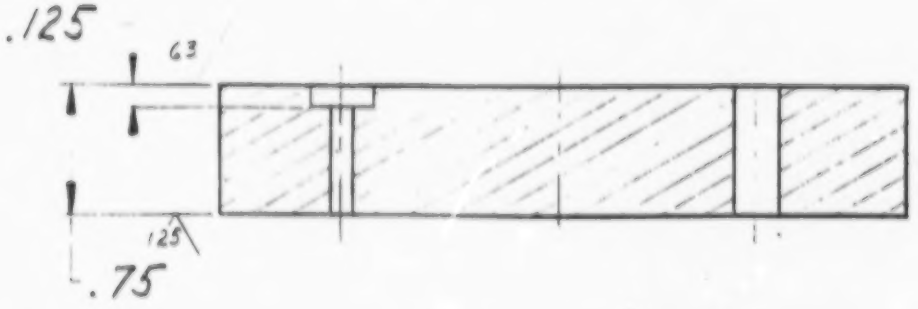
XXX ±.005 XXXX ±.0005	COURSE TOOL + DIE	SCALE FULL	MAT'L ALU. REQ. 1

SHEET 5 OF 7



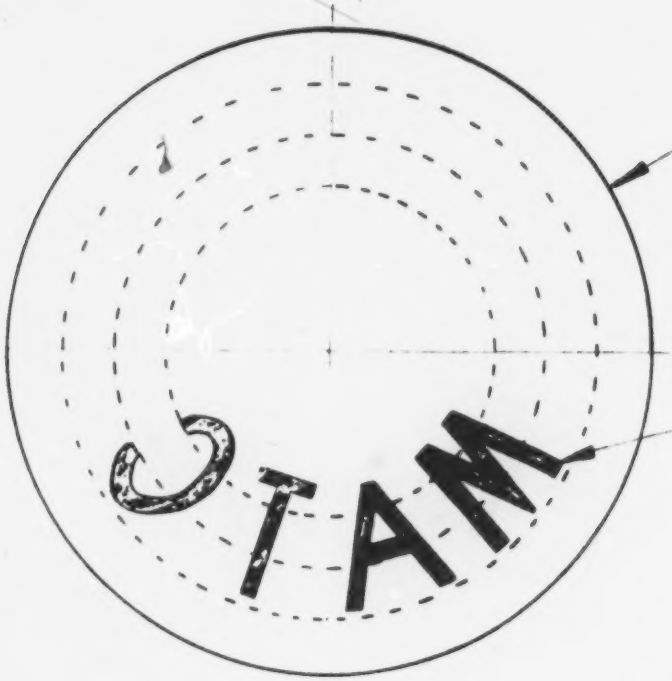
NG	DET. 5		SHEETS 5 OF 7
.XXX ±.005 .XXX ±.0005	COURSE TOOL + DIE	SCALE FULL	MAT'L ALU. REQ 1

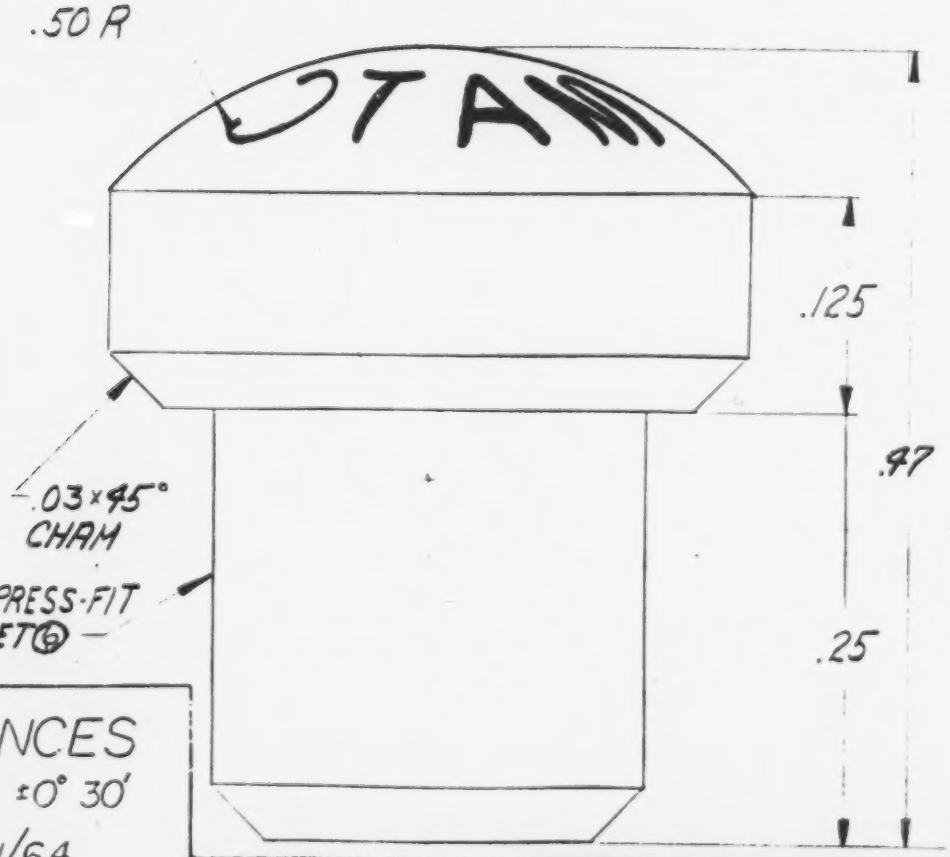




SECTION A-A

TOLERANCES		DET.	
ANGULAR ±0° 30'	BASE	6	SHEETS 6 OF 7
FRAC. ±1/64			
.XXX ±.005	COURSE	SCALE	MAT'L. ALU.
.XXXX ±.0005	TOOL # DIE 178	FULL	REQ. 1





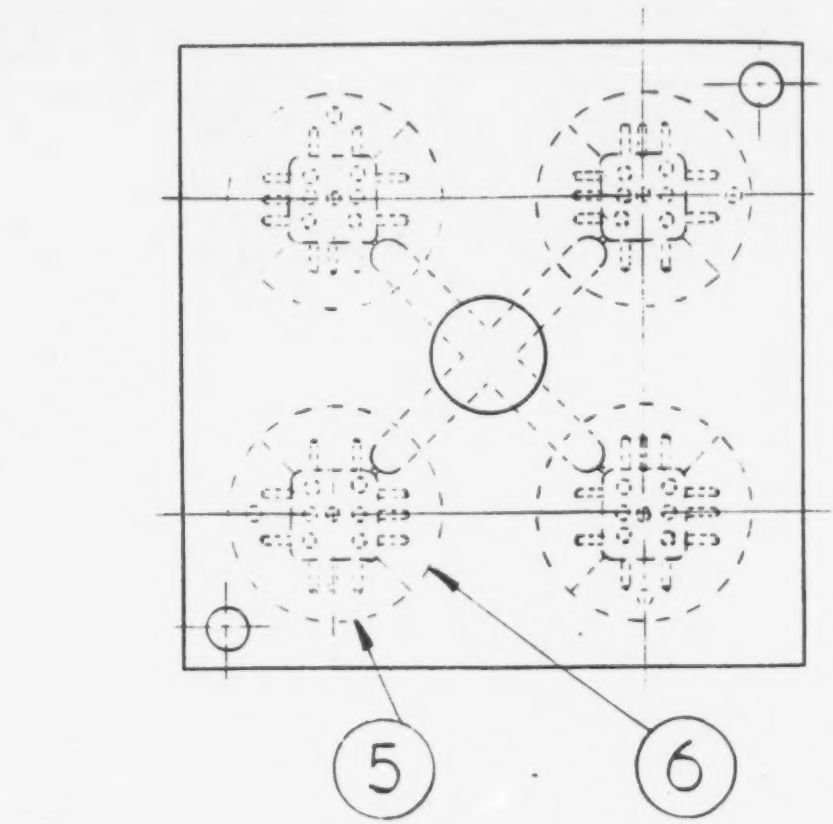
SHEETS 7 OF 7

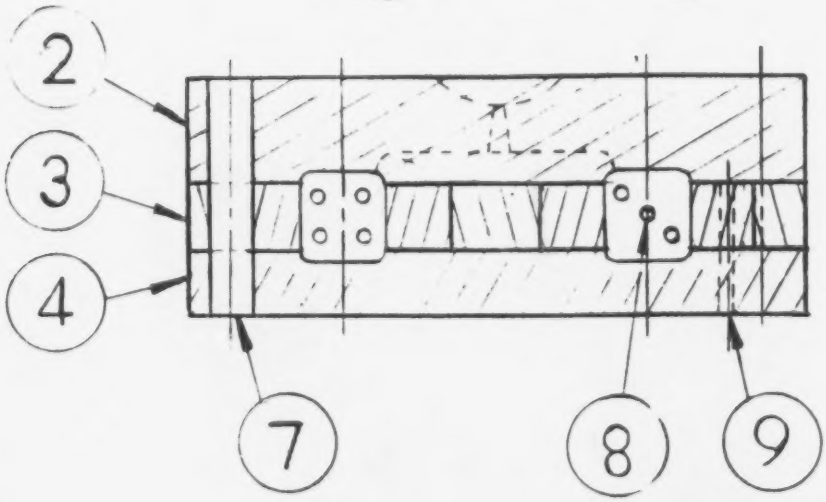
TEE HEAD

DET. 7

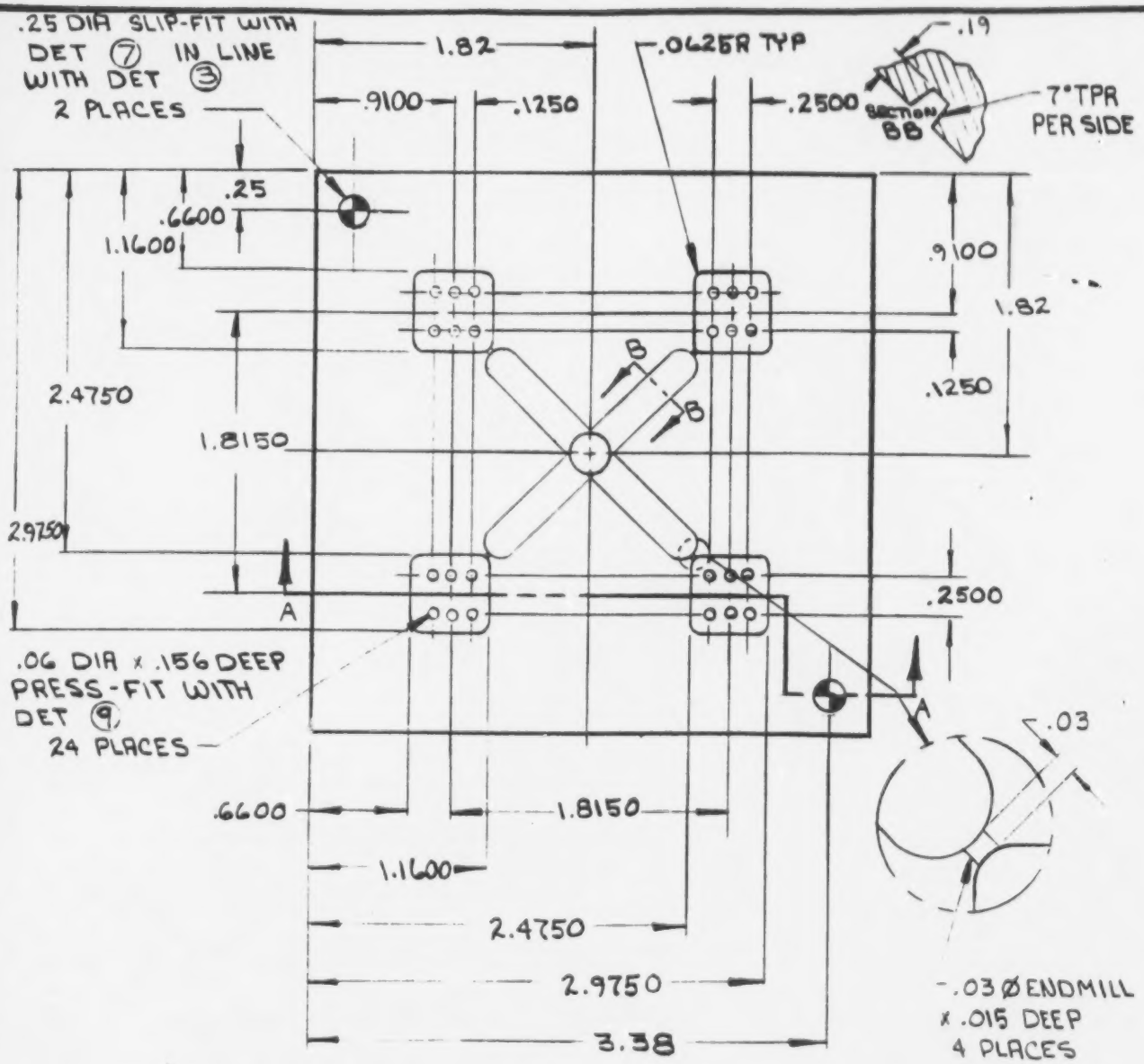
TOLERANCES
ANGULAR ±0° 30'
FRAC. ±1/64
.XXX ±.005
.XXXX ±.0005

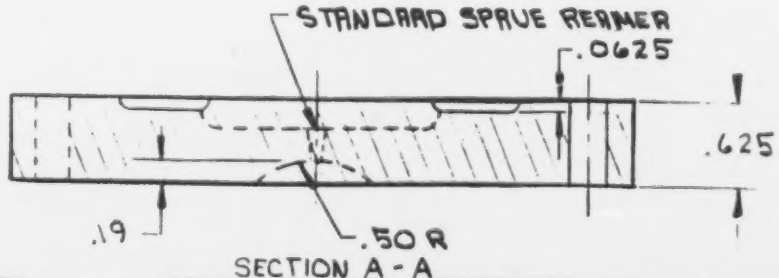
COURSE	SCALE	MAT'L. ALU.
TOOL + DIE	1 TO 10	REQ 9





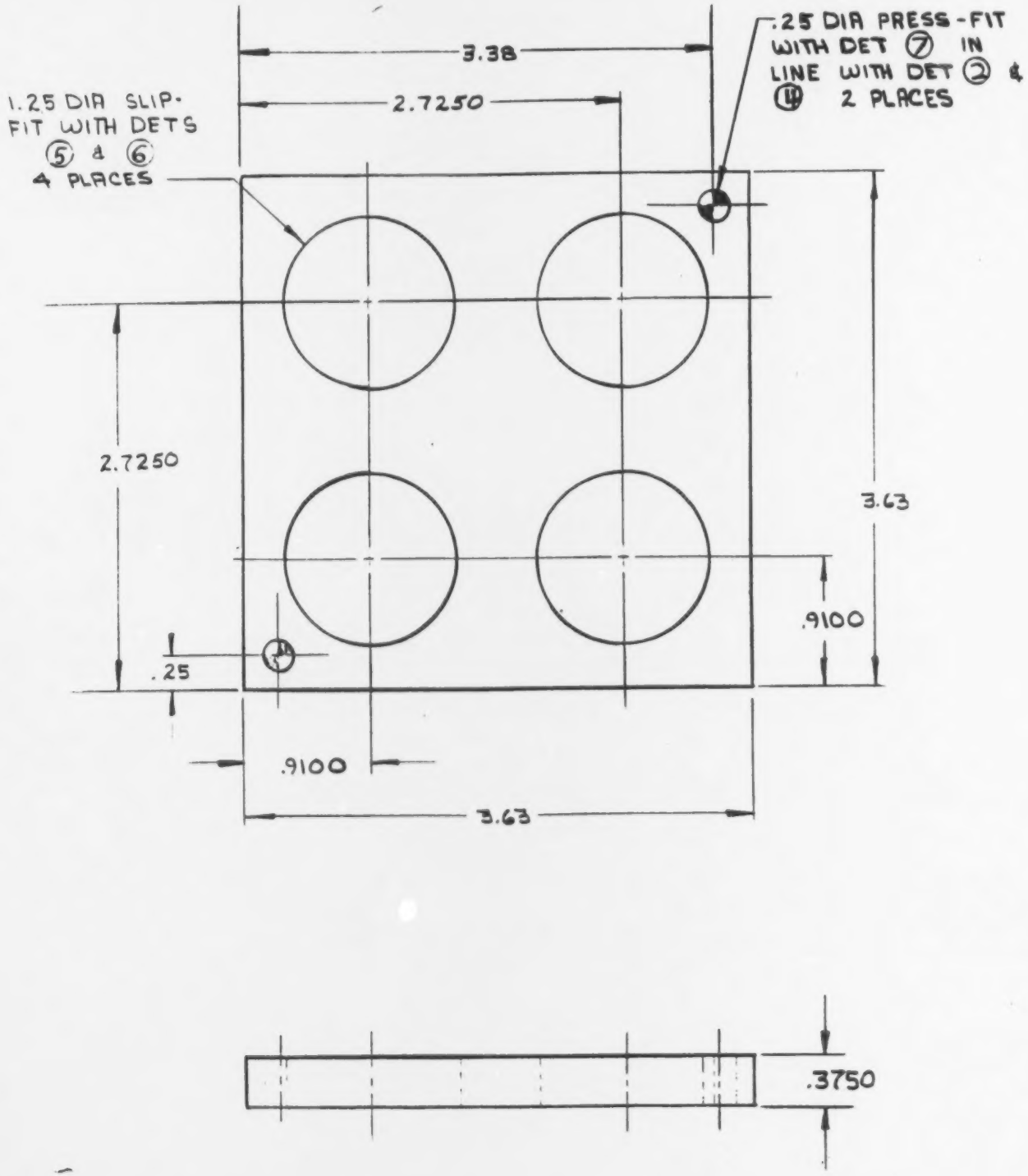
ANG ±	MATL:	TOOL AND DIE MAKING
FRAC ±	NO. REQ.	DICE MOLD
XX ±	DET. NO.	
XXX ±	Scale:	Sh 1 of 7
XXXX ±		



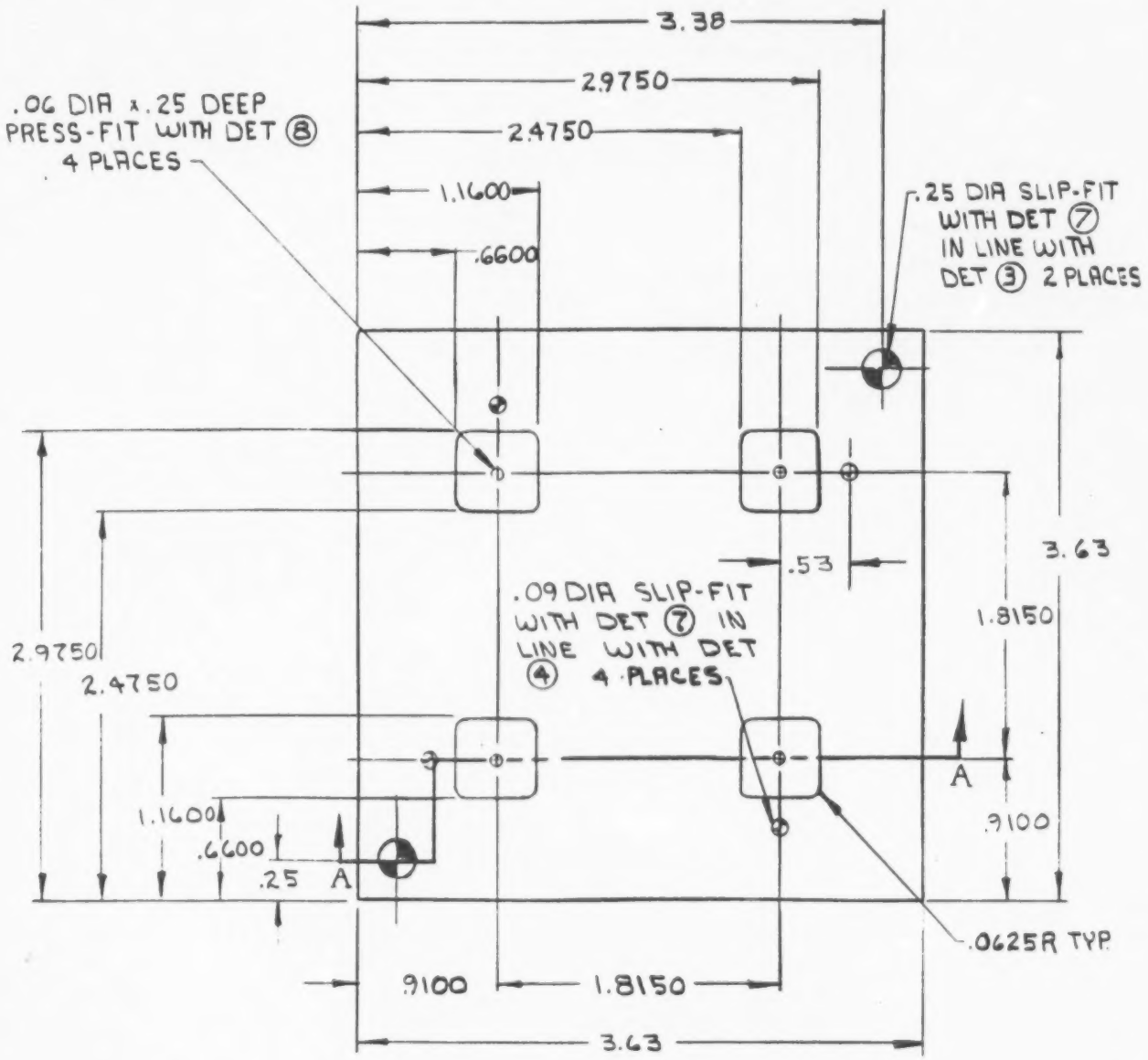


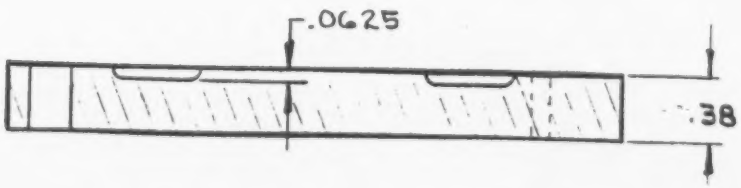
SECTION A-A

ANG ± 0°30′ FRAC ± XX ± .010 XXX ± .005 XXXX ± .0005	MATL: ALU. NO. REQ. 1 DET. NO. 2	TOOL AND DIE MAKING DICE MOLD	
		Scale: FULL	Sh 2 of 7

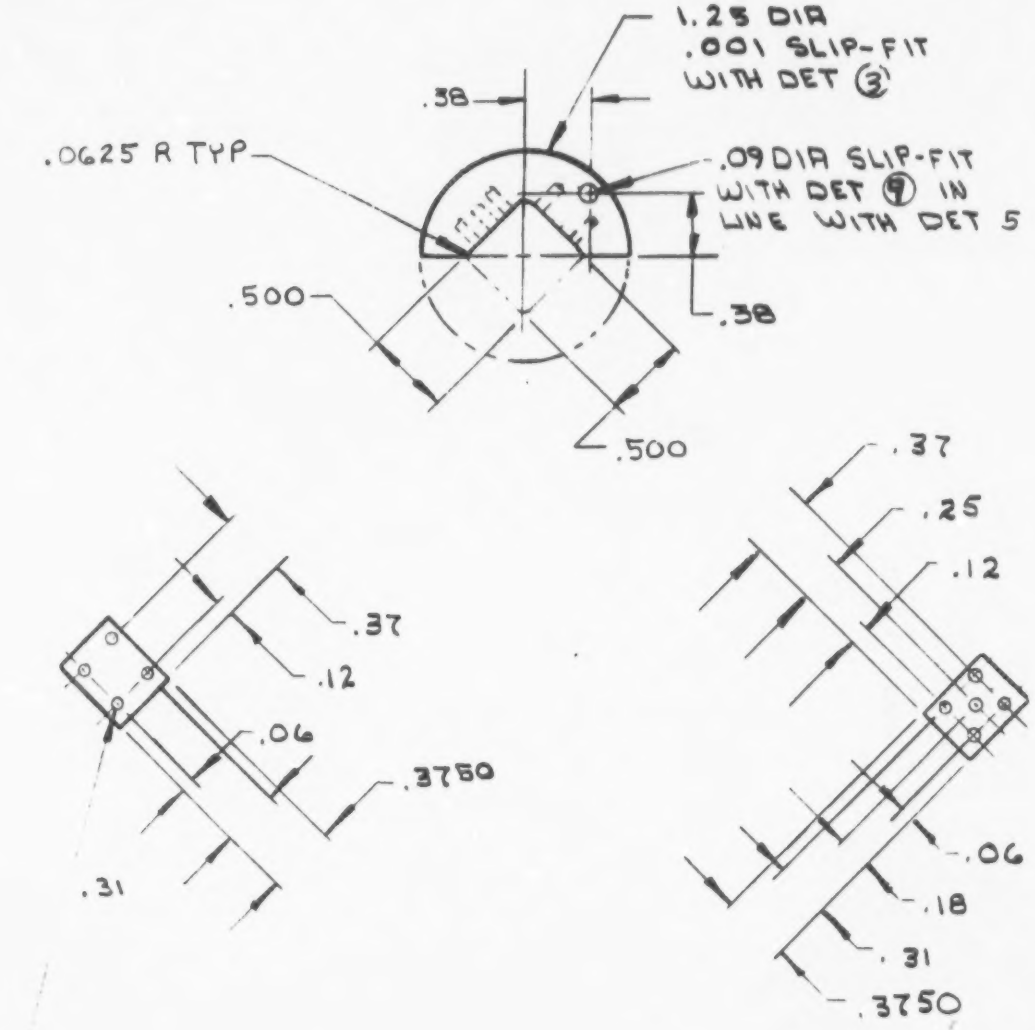


ANG ± 0°30'	MATL: ALU.	TOOL AND DIE MAKING	
FRAC ±	NO. REQ. 1	DICE MOLD	
XX ± .010	DET. NO. 3	Scale: FULL	Sh 3 of 7
XXX ± .005			
XXXX ± .0005			

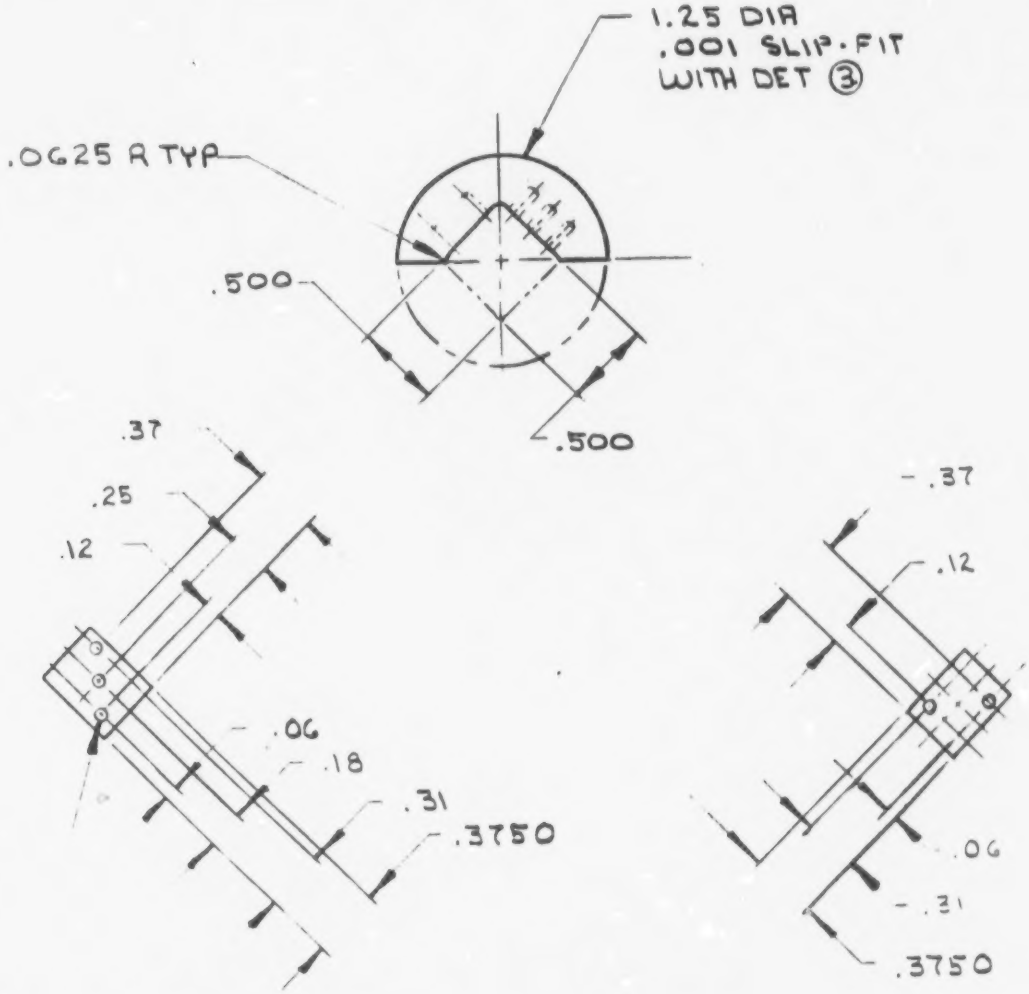




ANG ± 0° 30′ FRAC ± XX ± .010 XXX ± .005 XXXX ± .0005	MATL: ALU. NO. REQ. 1 DET. NO. 4	TOOL AND DIE MAKING DICE MOLD	
		Scale: FULL	Sh 4 of 7

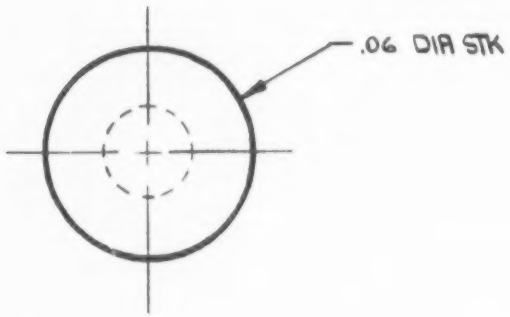


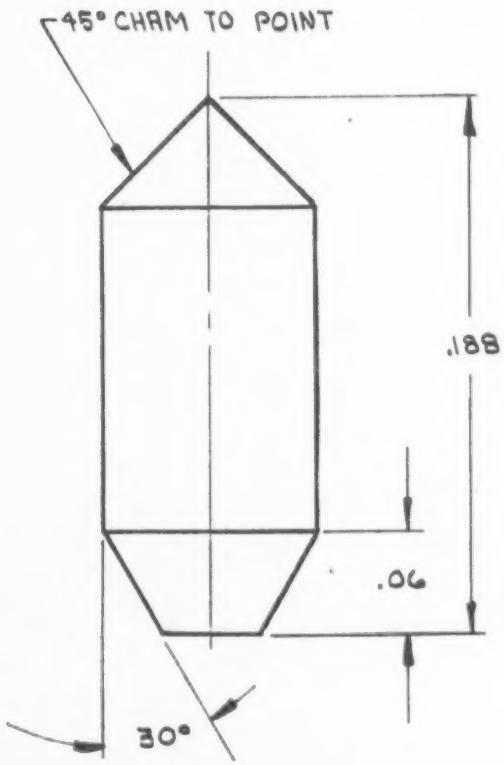
ANG ± 0°30'	MATL: ALU.	TOOL AND DIE MAKING	
FRAC ±	NO. REQ. 4	DICE MOLD	
XX ± .010	DET. NO. 5	Scale: FULL	Sh 5 of 7
XXX ± .005			
XXXX ± .0005			



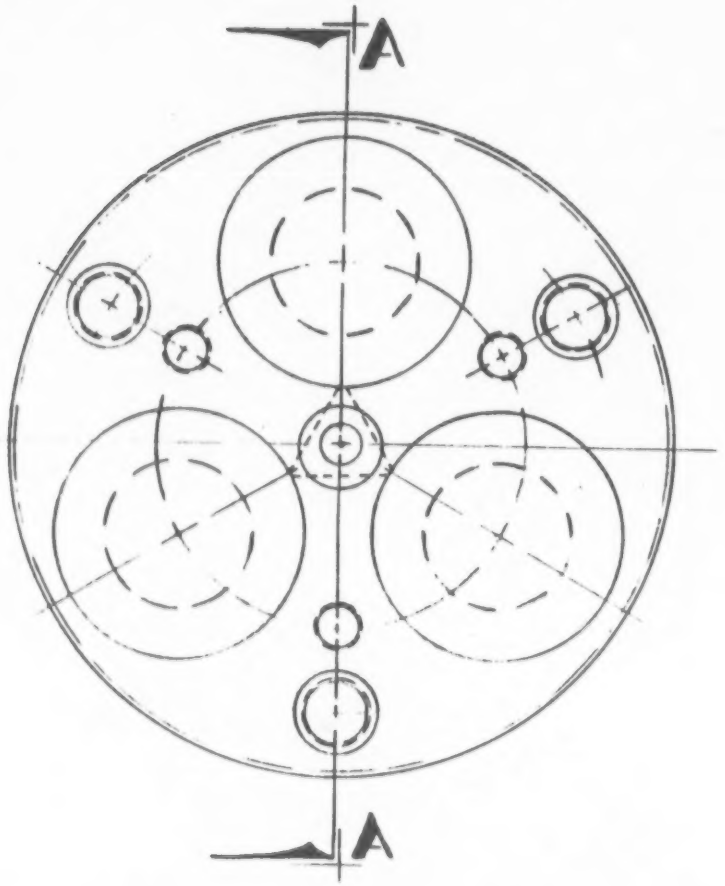
.06 DIA x .156 DEEP
PRESS-FIT WITH DET ②
7 PLACES

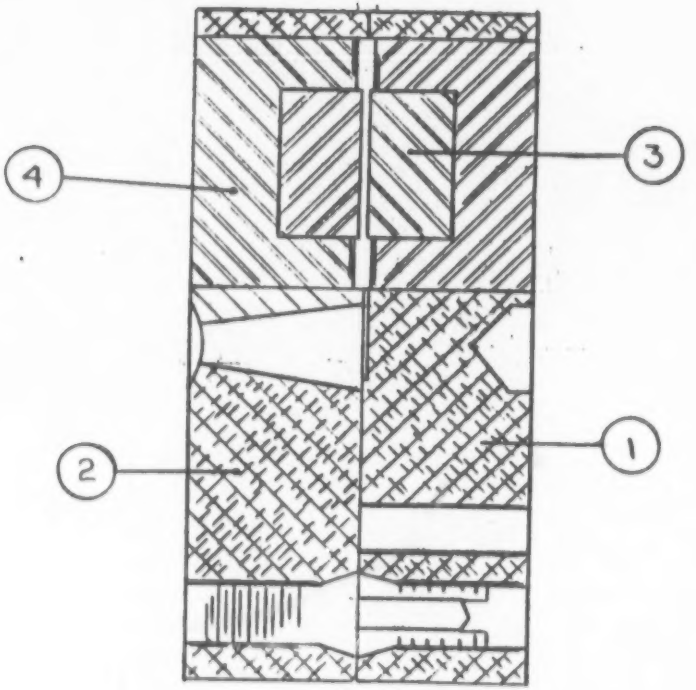
ANG ± 0°30'	MATL: ALU.	TOOL AND DIE MAKING	
FRAC ±	NO. REQ. 4	DICE MOLD	
XX ± .010	DET. NO. 6	Scale: FULL	Sh 6 of 7
XXX ± .005			
XXXX ± .0005			





ANG ± 0° 30'	MATL: MS	TOOL AND DIE MAKING	
FRAC ±	NO. REQ. 92	DICE MOLD	
XX ± .010	DET. NO. 8		
XXX ± .005		Scale: 1" = 1/2"	Sh 7 of 7
XXXX ± .0005			





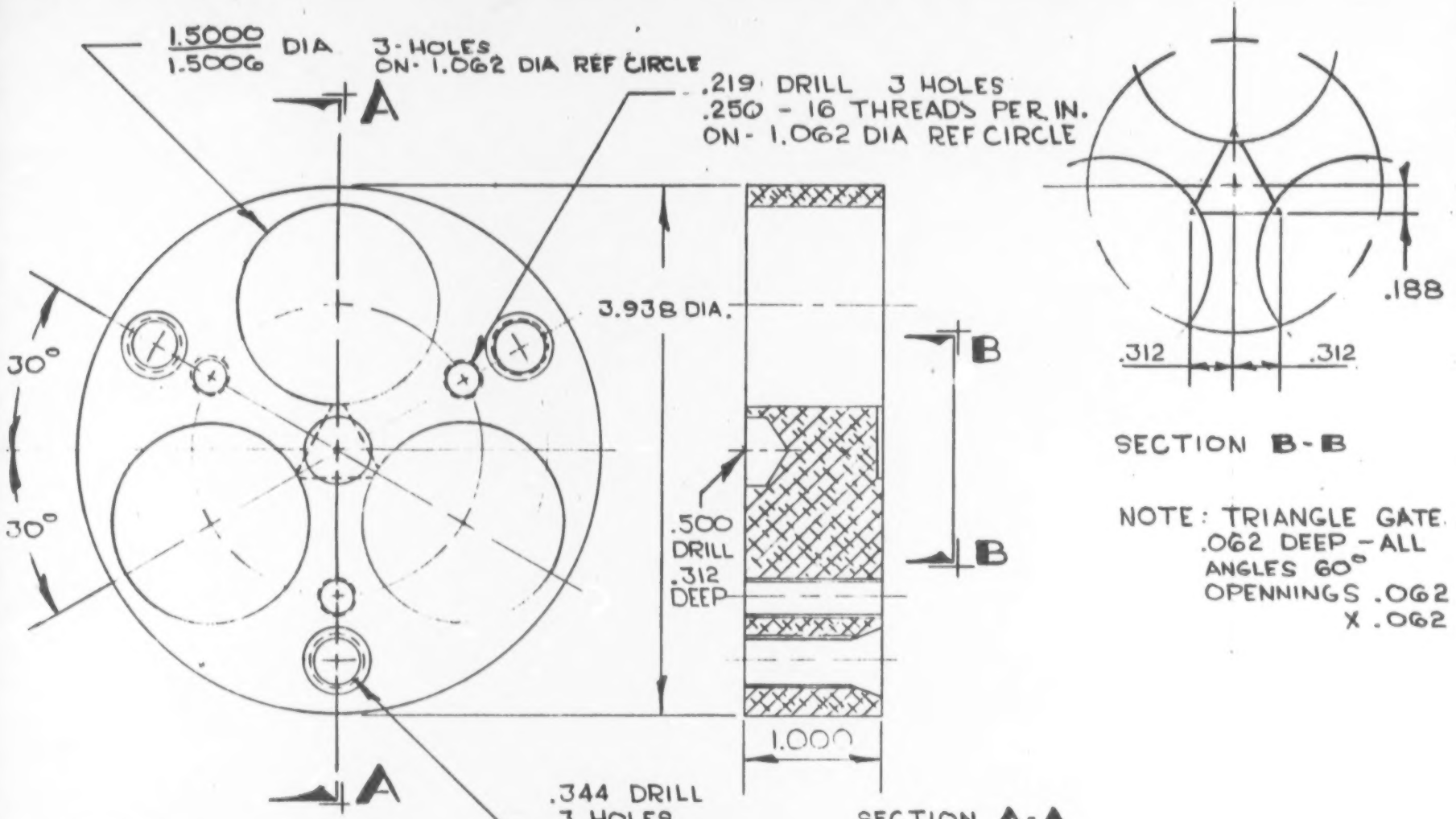
SECTION A-A

TOLERANCES
ANGULAR ±0° 30'
FRAC. ±1/64
.XXX ±.005
.XXXX ±.0005

187

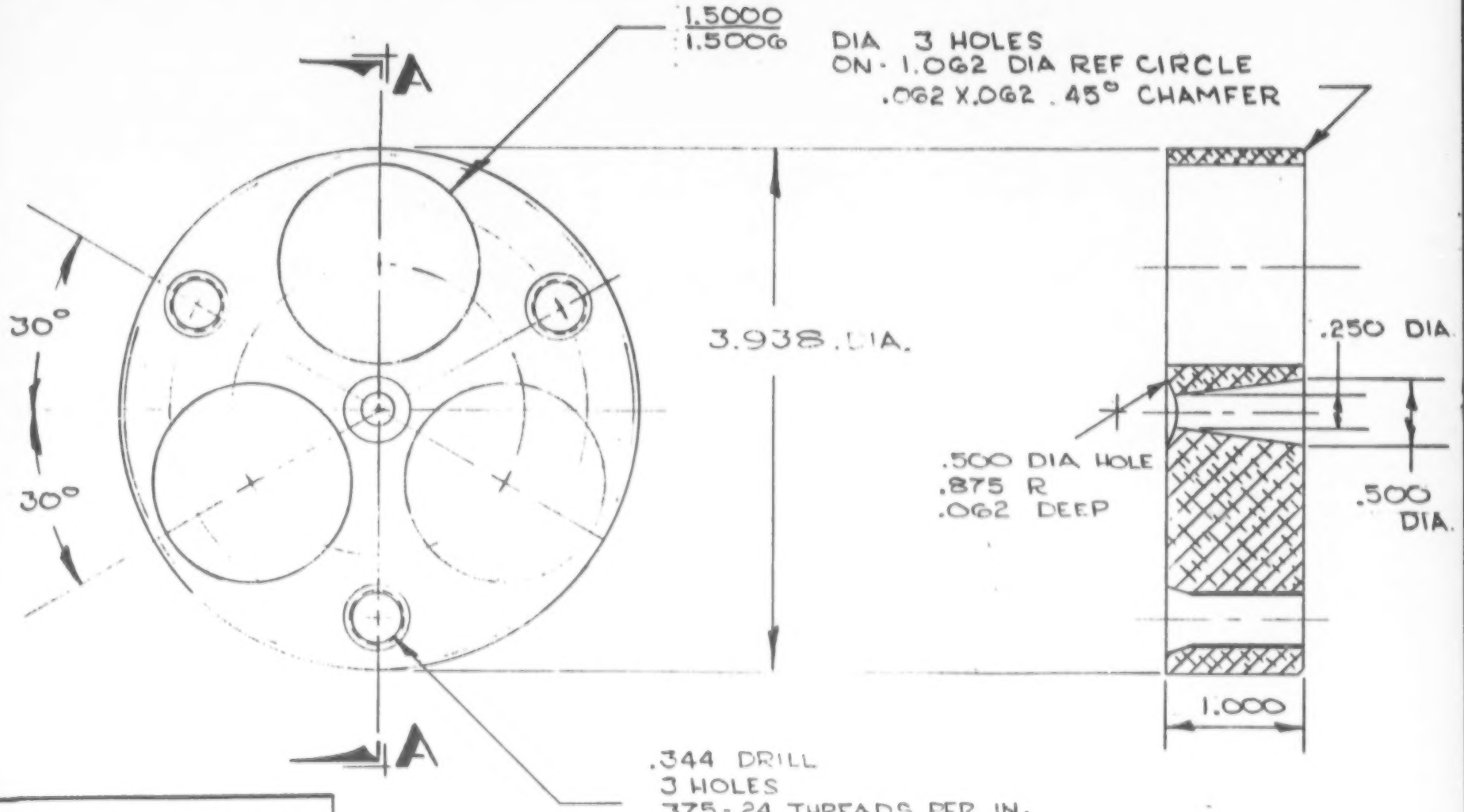
sh 1 of 4

COURSE	SCALE	MAT'L.		
TOOL + DIE	FULL	REQ. 1	ASSEMBLY	188



TOLERANCES					
ANGULAR ±0° 30'	Sh 2 of 4				
FRAC. ±1/64	COURSE	SCALE	MAT'L. ALU.	BOTTOM	DET.
.XXX ±.005	TOOL + DIE	FULL	REQ. 1		1
.XXXX ±.0005					

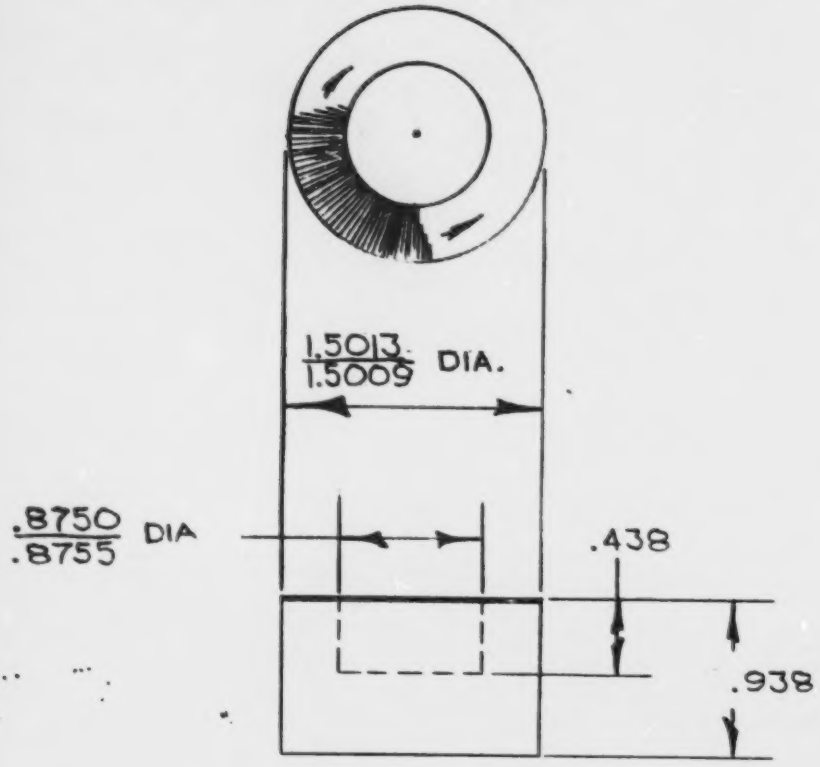
189 190



TOLERANCES
ANGULAR ±0° 30'
FRAC. ±1/64
.XXX ±.005
.XXXX ±.0005

Sh 3 of 4

COURSE	SCALE	MAT'L.		DET.
TOOL & DIE	FULL	REQ. 1	TOP	2



DET. 4

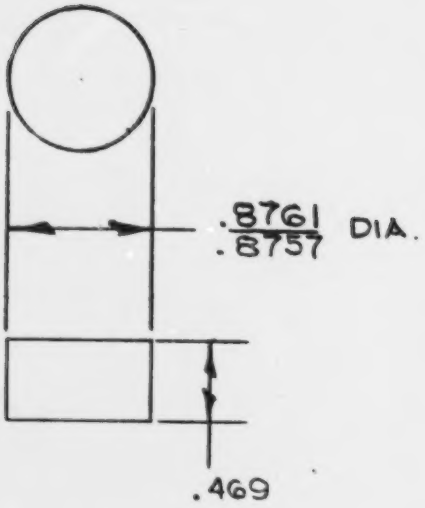
120 EQUALLY SPACED
.031 DEEP

TOLERANCES
ANGULAR ±0° 30'
FRAC. ±1/64
.XXX ±.005
.XXXX ±.0005

Sh. 4 of 4

COURSE
TOOL + DIE

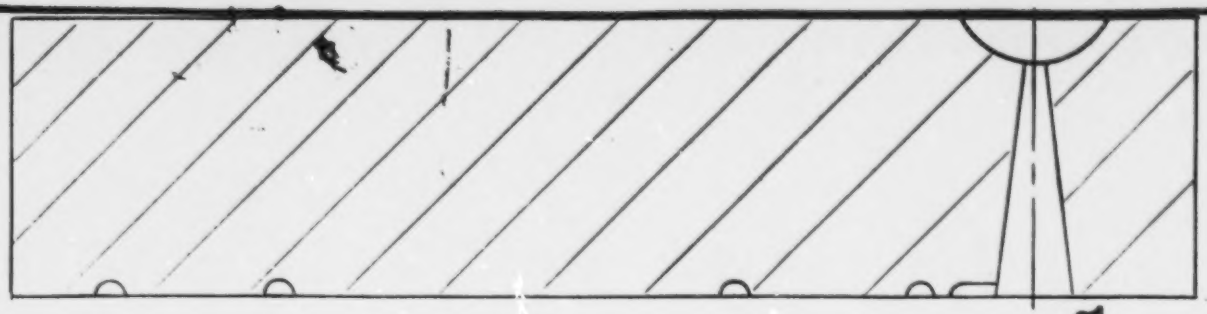
SCALE
FULL



DET. 3

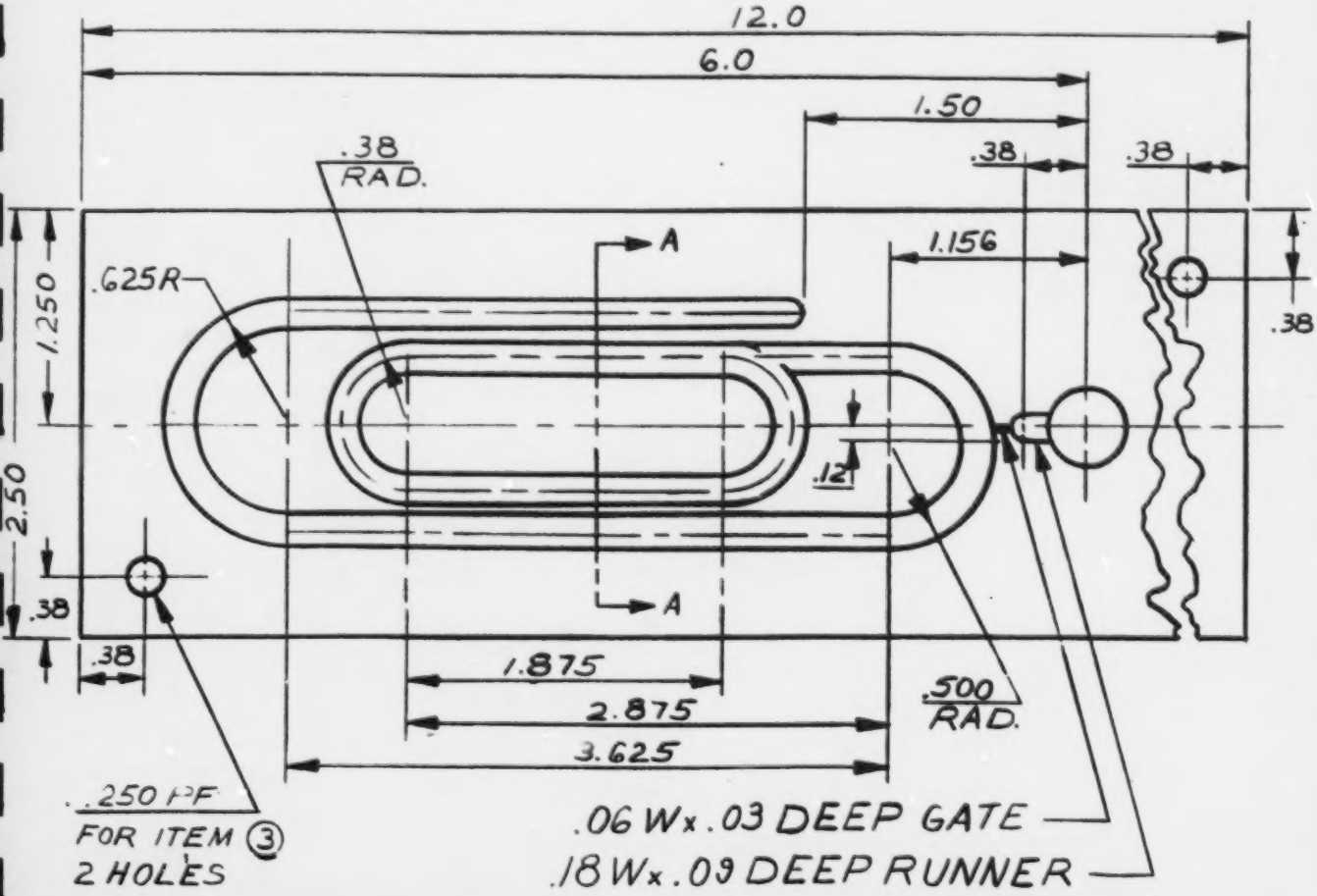
CUTS

MAT'L. ALU. REQ.3	DIE 194	DET. 3 & 4

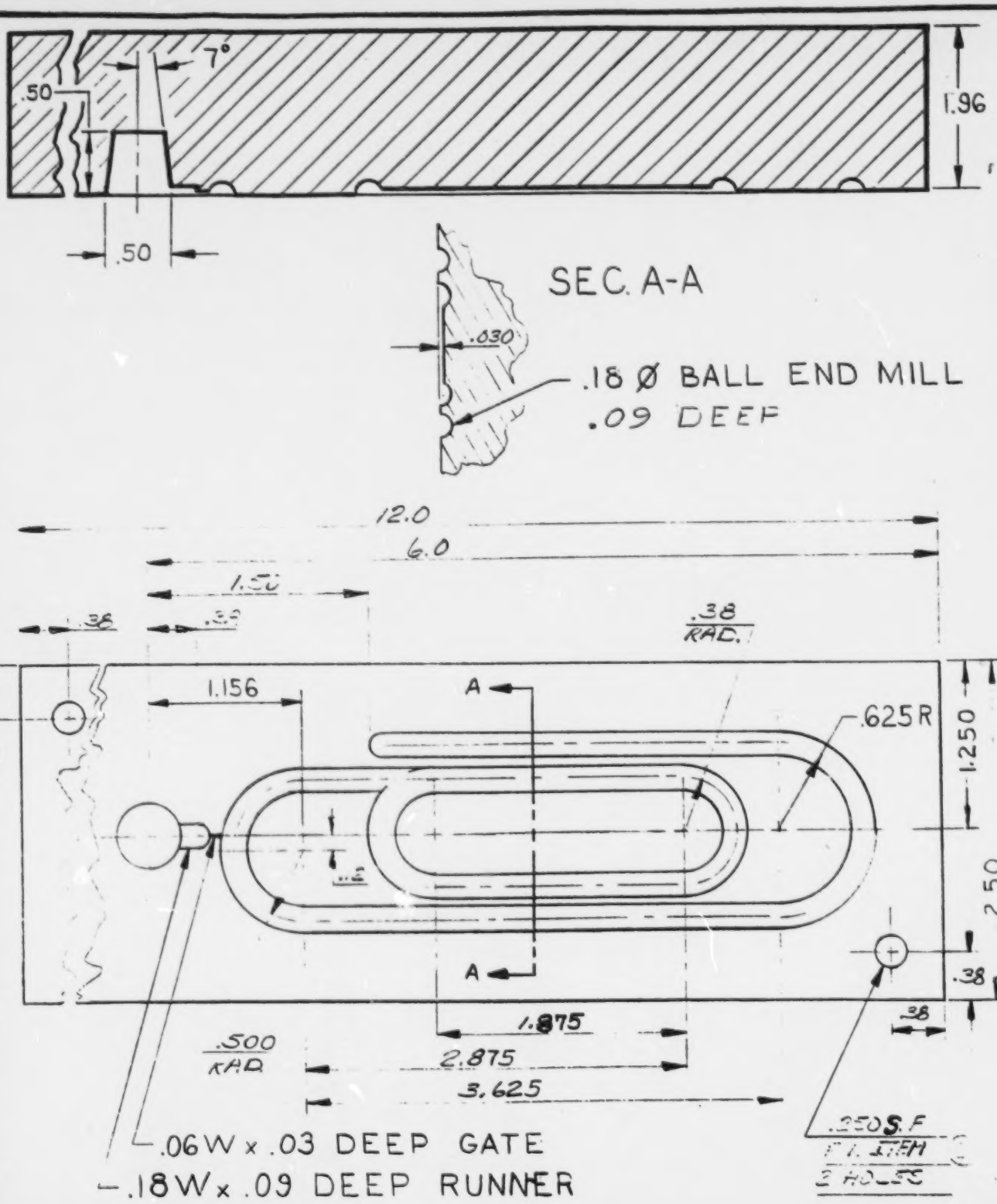


SEC. A-A

.18 Ø BALL ENDMILL
.09 DEEP



ANG ± 1°	MATL: ALUM.	TOOL AND DIE MAKING	
FRAC ±	NO. REQ. 1	PAPER CLIP MOLD	
XX ± .015	DET. NO. 1		
XXX ± .002	BOTTOM	Scale: FULL	Sh 1 of 2
XXXX ± .0005			



ANG ± 1°	MATL: ALUM.	TOOL AND DIE MAKING	
FRAC ±	NO. REQ. 1	PAPER CLIP MOLD	
XX ± .015	DET. NO. 2		
XXX ± .002	TOP	Scale: FULL	Sh 2 of 2
XXXX ± .0005			

BILL OF MATERIAL

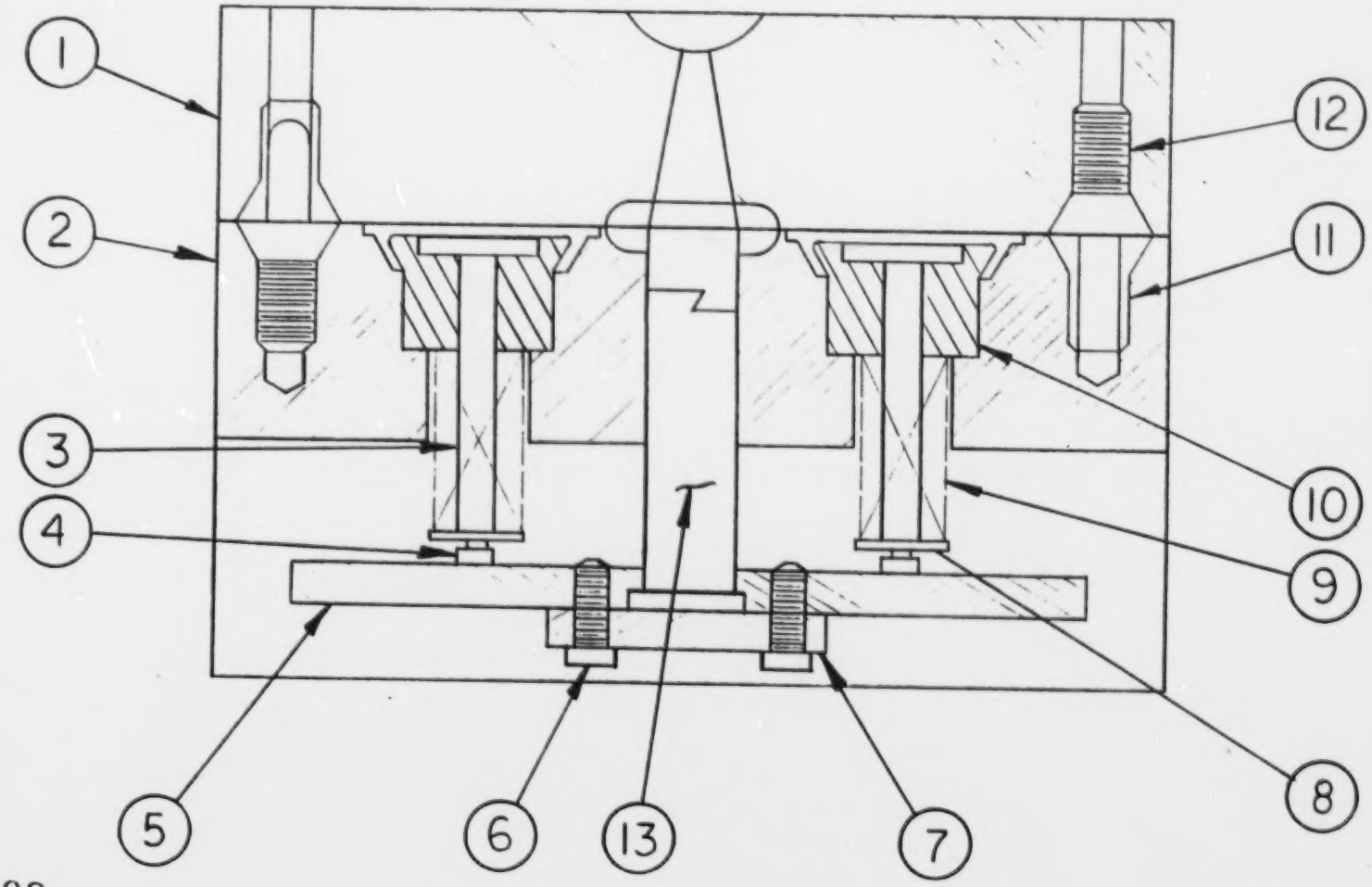
ITEM	QTY.	MATERIAL	DESCRIPTION
1	1	AL	$6\frac{1}{8} \times 6\frac{1}{8} \times 1\frac{1}{2}$
2	1	AL	$6\frac{1}{8} \times 6\frac{1}{8} \times 2$
3	2	1018	1 DIA X $2\frac{1}{8}$
1	2		5100-25, RETAINING RING
5	1	1018	$\frac{1}{4} \times 3\frac{1}{2} \times 5$
6	2		#10-32 UNF, HEX HD SCREW
7	1	1018	$\frac{1}{4} \times 1\frac{1}{4} \times 1\frac{3}{4}$
8	2		$\frac{1}{4}$ PLAIN WASHER
2	2		LC-045H-4, SPRING
10	2	1018	$1\frac{1}{4}$ DIA X $\frac{7}{8}$
11	2		CL-B-8, ALIGNING PIN LINER
12	2		CL-8-B, ALIGNING PIN
13	1	1018	$\frac{7}{8}$ DIA X $2\frac{1}{8}$
14	3		$\frac{1}{4}$-28 UNF SET SCREW

1 WALDES KOHINOOR, INC

2 LEE SPRING COMPANY, INC.

ANG ± ____ FRAC ± ____ XX ± ____ XXX ± ____ XXXX ± ____	MATL: ____ NO. REQ. ____ DET. NO. ____ D. ZINKIEWICZ	TOOL AND DIE MAKING BOTTLE CAP MOLD Scale: / Sh 1 of 12

BOTTLE CAP MOLD



ANG ±
FRAC ±
XX ±
XXX ±
XXXX ±

MATL:
NO. REQ.
DET. NO.

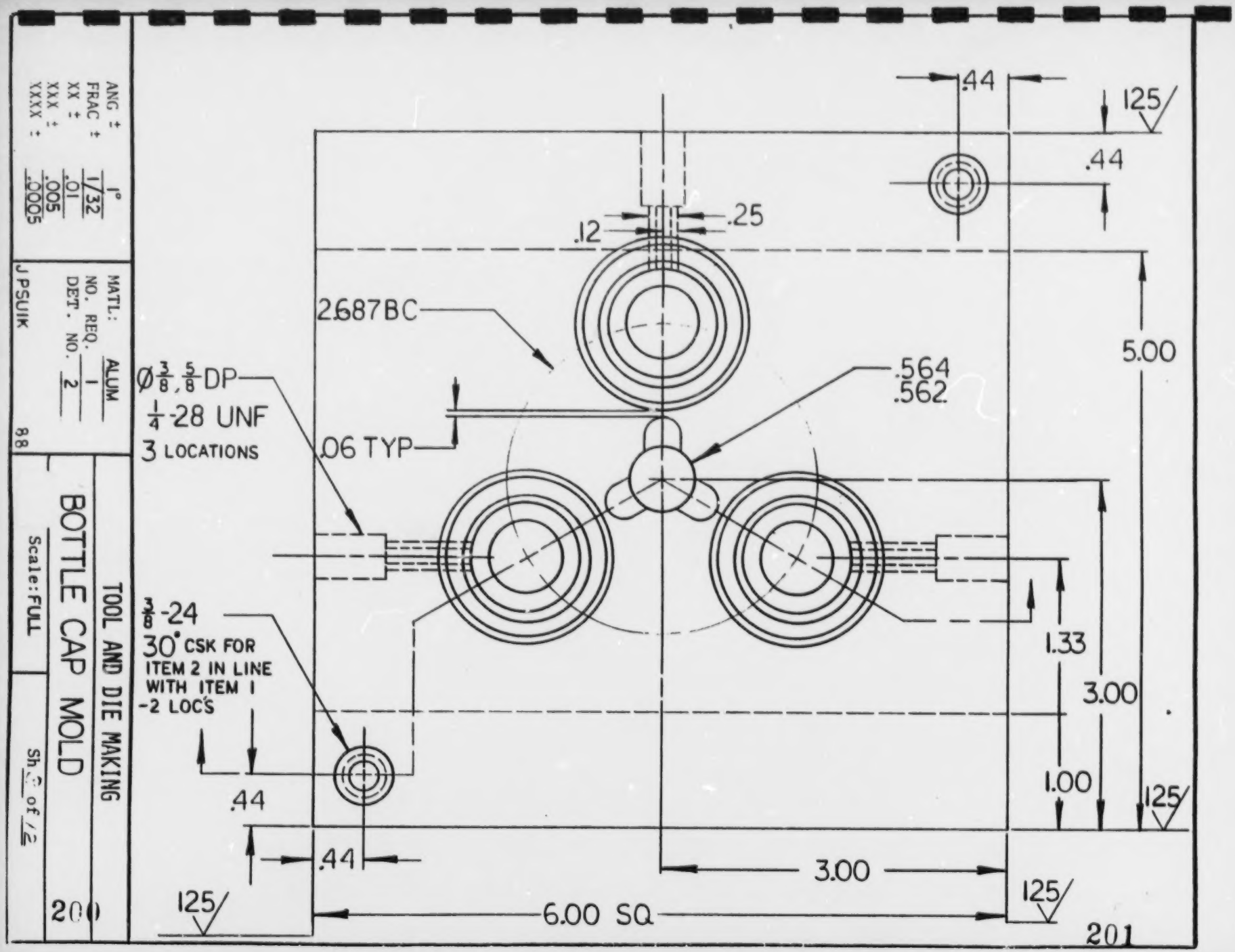
J PSUIK 88

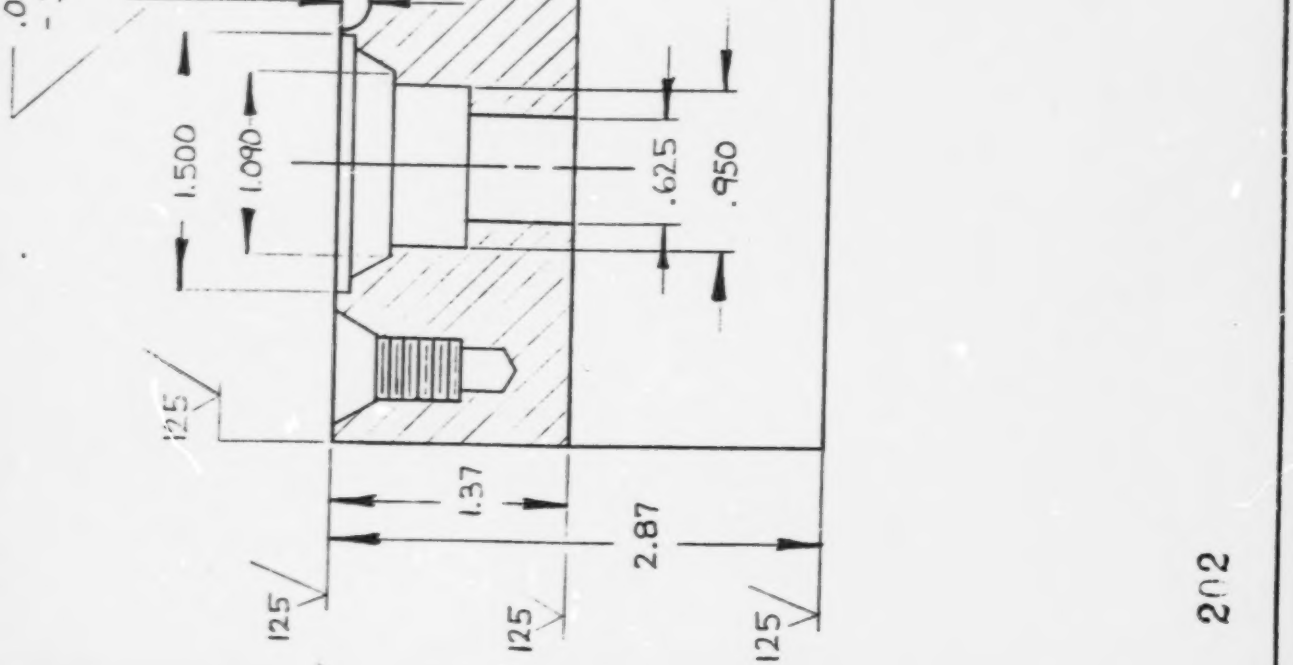
TOOL AND DIE MAKING

ASSEMBLY

Scale: FULL

Sh 2 of 12

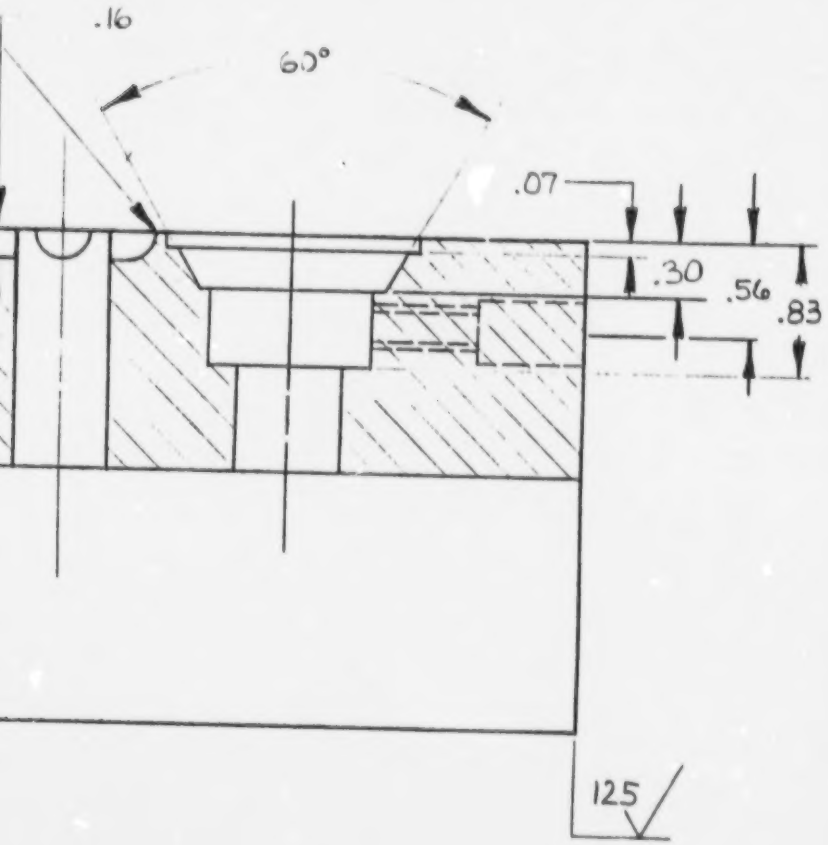

ANG ±
FRAC ± 1/32
XX ± .01
XXX ± .005
XXXX ± .0005
MATL: ALUM
NO. REQ. 1
DET. NO. 2
J PSUIK
88
TOOL AND DIE MAKING
BOTTLE CAP MOLD
Scale: FULL
Sh 2 of 12
200
.44
125
.44
.12
.25
2.687 BC
Ø 3/8, 5/8 DP
1/4-28 UNF
3 LOCATIONS
.06 TYP
.564
.562
5.00
3/8-24
30° CSK FOR
ITEM 2 IN LINE
WITH ITEM 1
-2 LOC'S
1.33
3.00
1.00
.44
.44
125
3.00
125
125
6.00 SQ
201

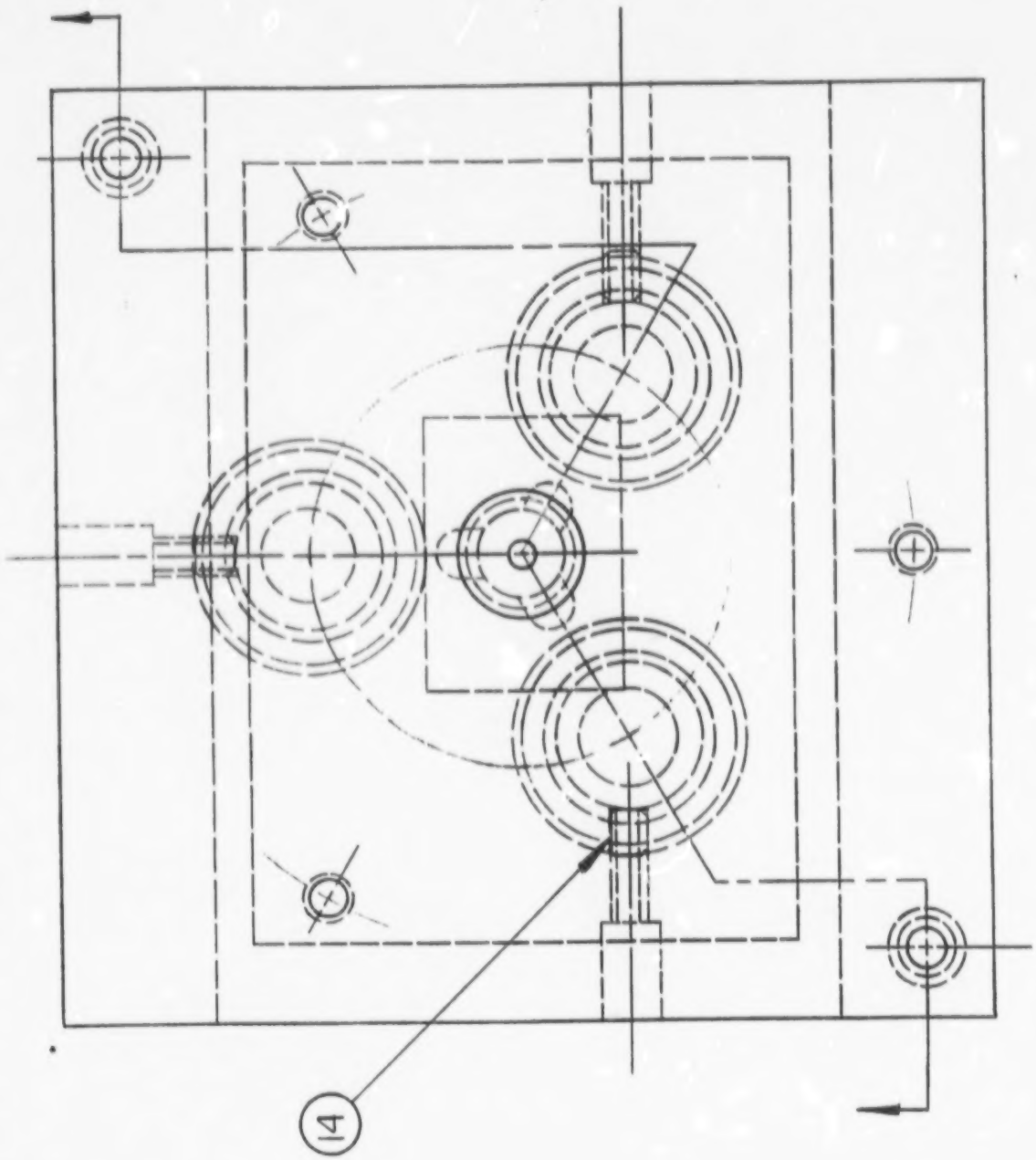


202

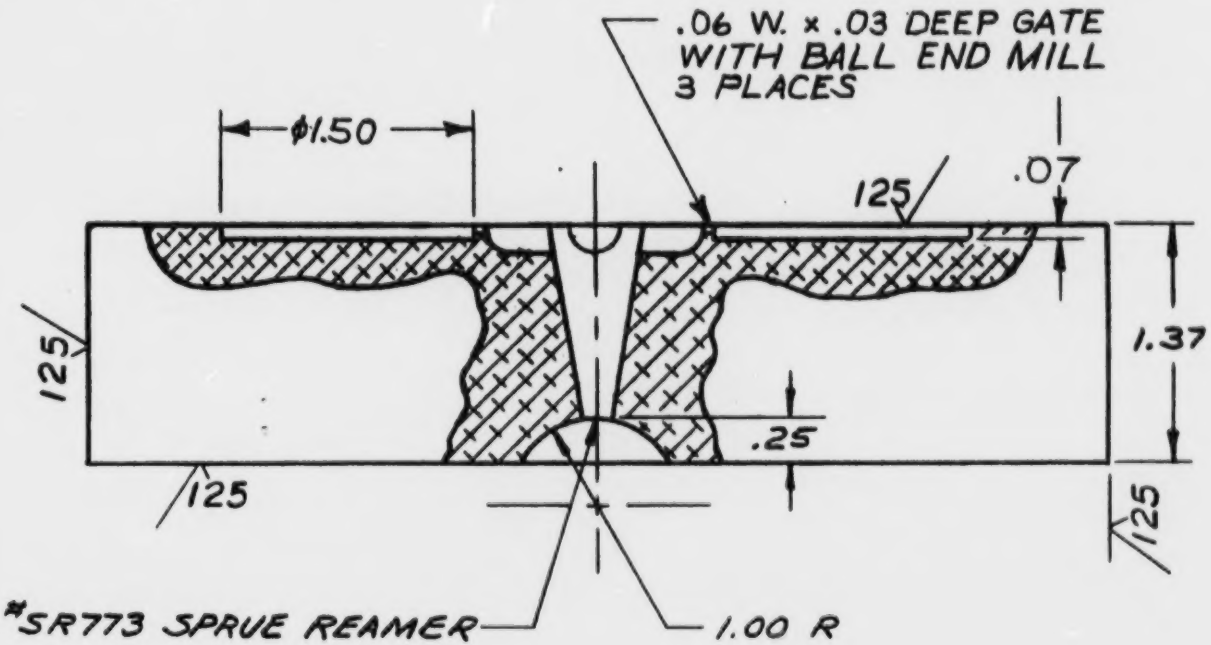
ANG ± 2°	MATL: ALUM	TOOL AND DIE MAKING	
FRAC ±	NO. REQ. 1	BOTTLE CAP MOLD	
XX ± .01	DET. NO. 2		
XXX ± .005	J PSUIK 88	Scale: FULL	Sh 4 of 12
XXXX ±			

6 WIDE x .03 DEEP GATE WITH BALL END MILL
3 LOCATIONS





ANG ± ____	MATL: ____	TOOL AND DIE MAKING
FRAC ± ____	NO. REQ. ____	BOTTLE CAP MOLD
XX ± ____	DET. NO. ____	
XXX ± ____		Scale: FULL
XXXX ± ____	J PSUIK 88	Sh. 2 of 2



TOOL AND DIE MAKING

BOTTLE CAP MOLD

Scale: FULL

Sh 6 of 12

MATL: AL

NO. REQ. 1

DET. NO. 1

D ZINKIEWICZ

ANG ± —

FRAC ± .015

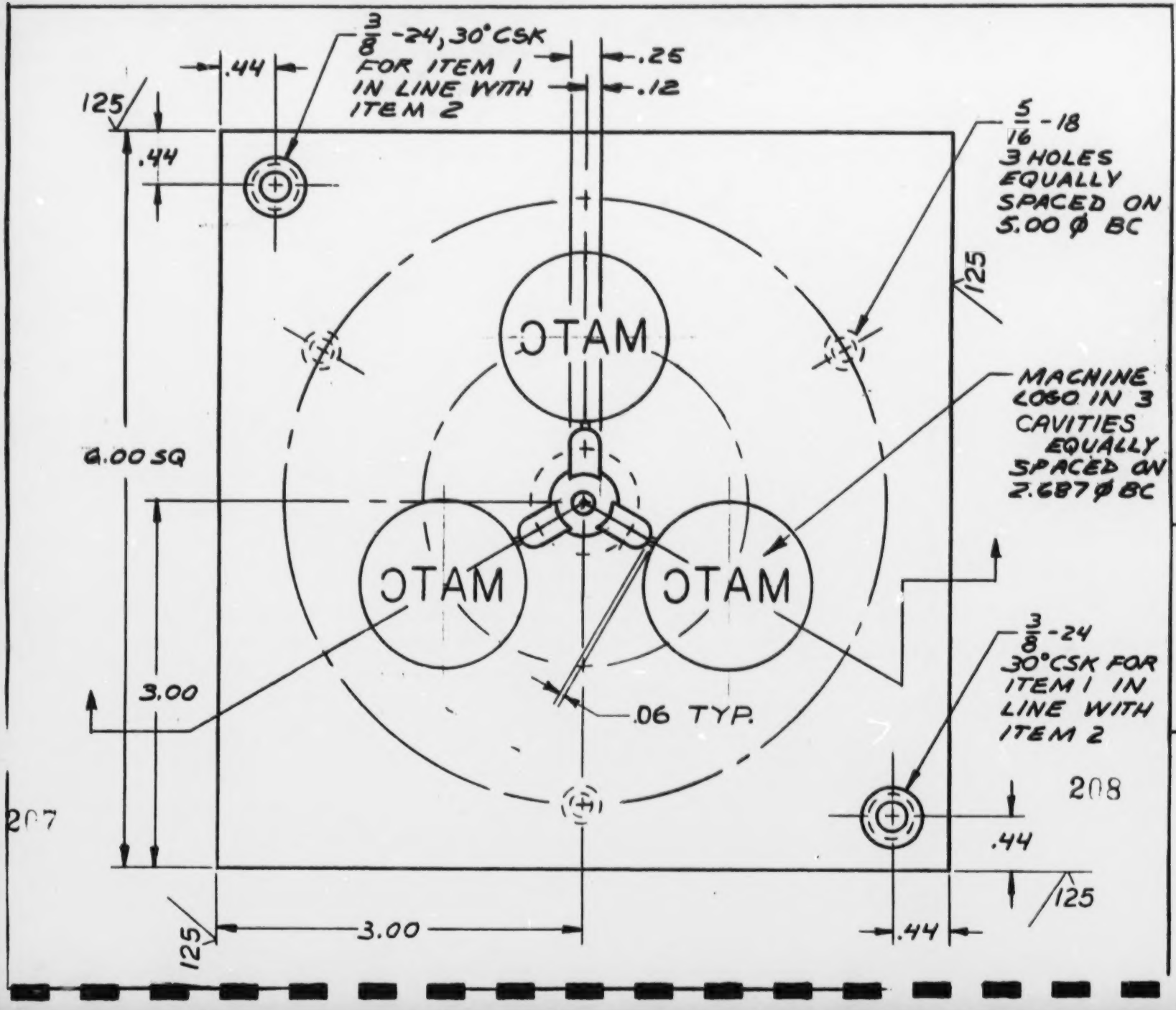
XX ± .005

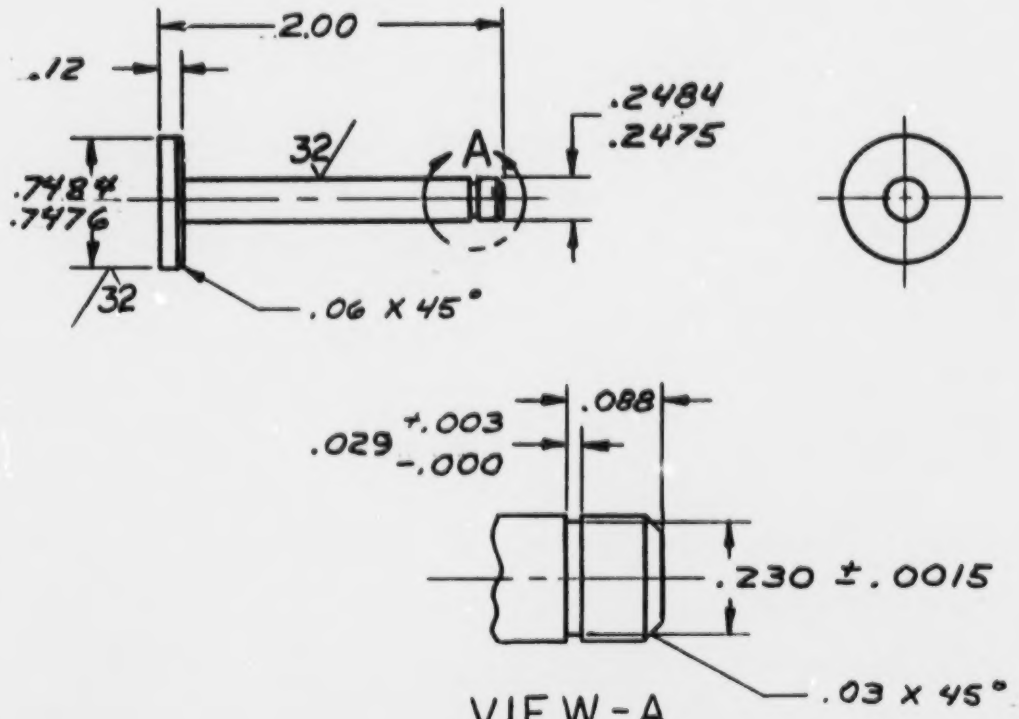
XXX ± —

XXXX ± —

205

206


3/8-24, 30° CSK FOR ITEM 1 IN LINE WITH ITEM 2
.44
.25
.12
125
.44
5/16-18 3 HOLES EQUALLY SPACED ON 5.00 Ø BC
125
MACHINE LOGO IN 3 CAVITIES EQUALLY SPACED ON 2.687 Ø BC
CTAM
CTAM
CTAM
6.00 SQ
3.00
.06 TYP.
3/8-24 30° CSK FOR ITEM 1 IN LINE WITH ITEM 2
208
207
.44
125
3.00
125
.44
TOOL AND DIE MAKING
BOTTLE CAP MOLD
Scale: FULL
Sh 7 of 12
MATL: AL.
NO. REQ. 1
DET. NO. 1
D ZINKIEWICZ
ANG ±
FRAC ± 1/32
XX ± .015
XXX ± .005
XXXX ±



VIEW-A
3X SIZE

209

210

TOOL AND DIE MAKING

BOTTLE CAP MOLD

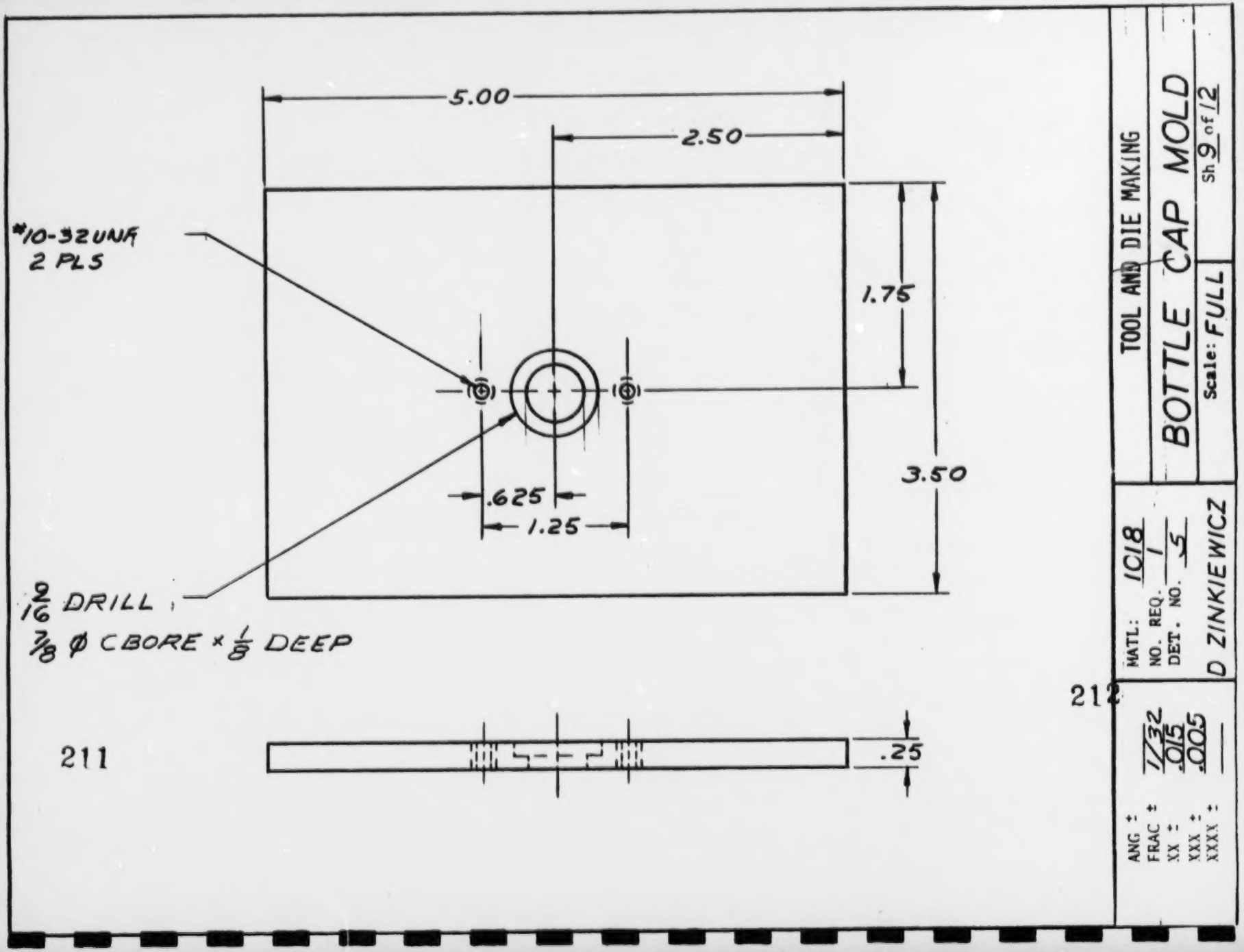
Scale: FULL

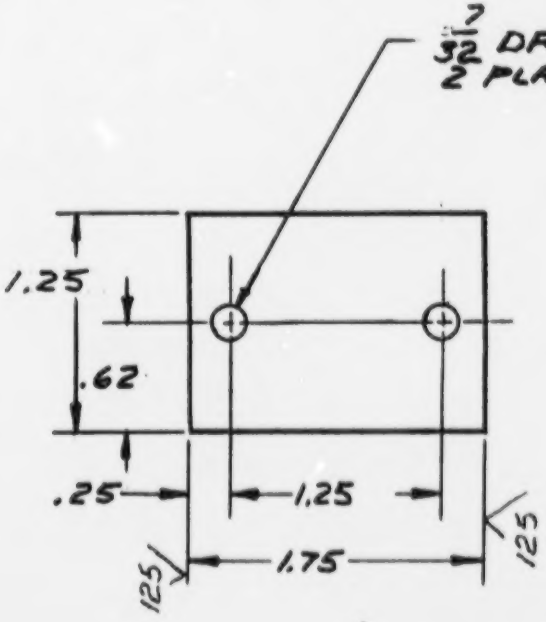
Sh 8 of 12

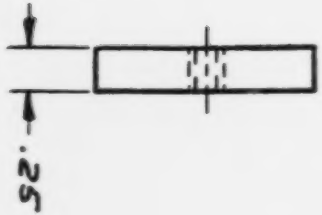
MATL: 1018
NO. REQ. 2
DET. NO. 3

D ZINKIEWICZ

ANG ± 2°
FRAC ± .015
XX ± .005
XXX ± —
XXXX ± —

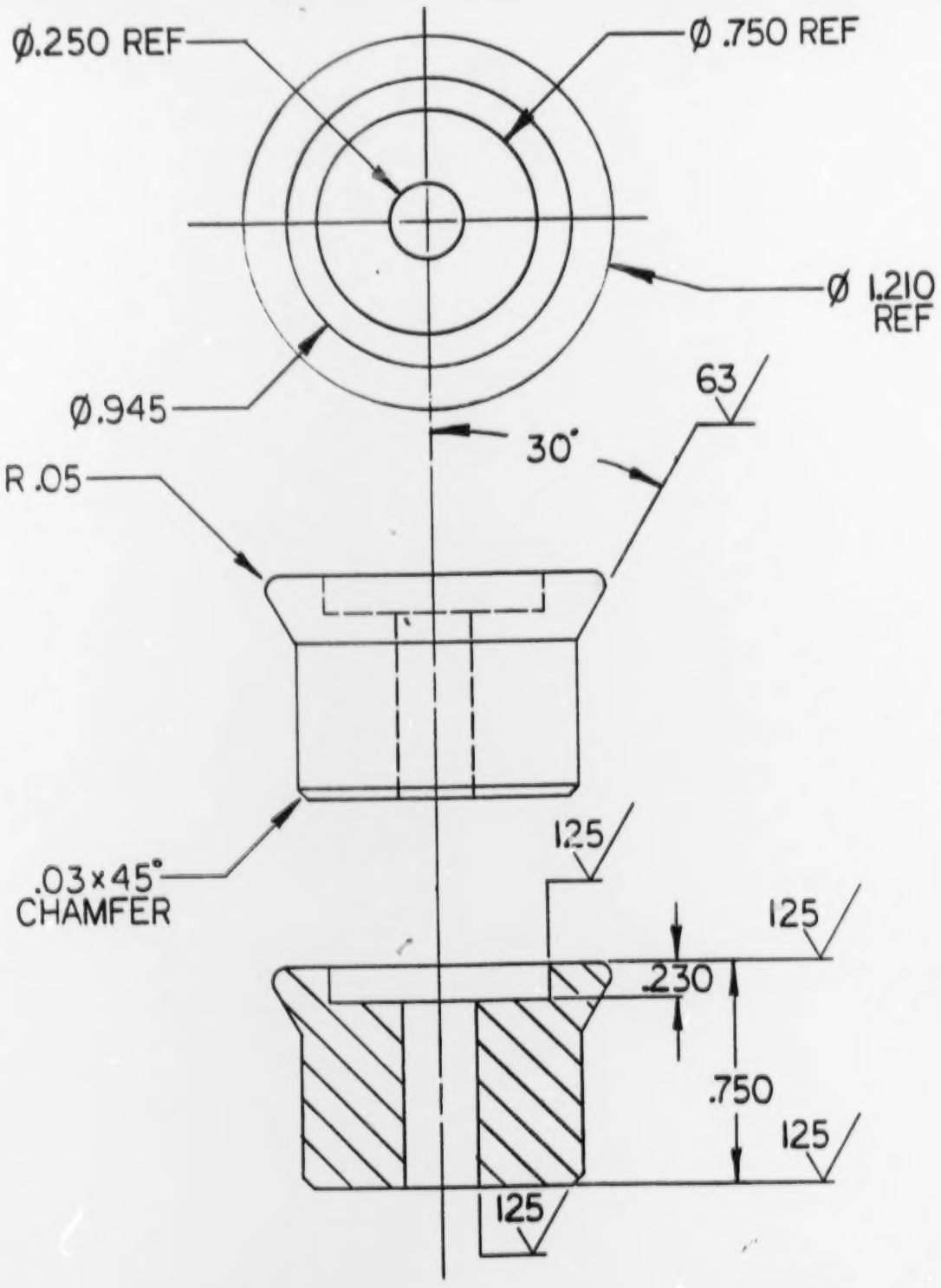

5.00
2.50
#10-32UNF
2 PLS
1.75
3.50
.625
1.25
9/16 DRILL
3/8 Ø CBORE × 1/8 DEEP
211
212
.25
TOOL AND DIE MAKING
BOTTLE CAP MOLD
Scale: FULL
Sh 9 of 12
MATL: 1018
NO. REQ. 1
DET. NO. 5
D ZINKIEWICZ
ANG ±
FRAC ± 1/32
XX ± .015
XXX ± .005
XXXX ±


7/32 DRI
2 PLAC
1.25
.62
.25
1.25
1.75
125
125

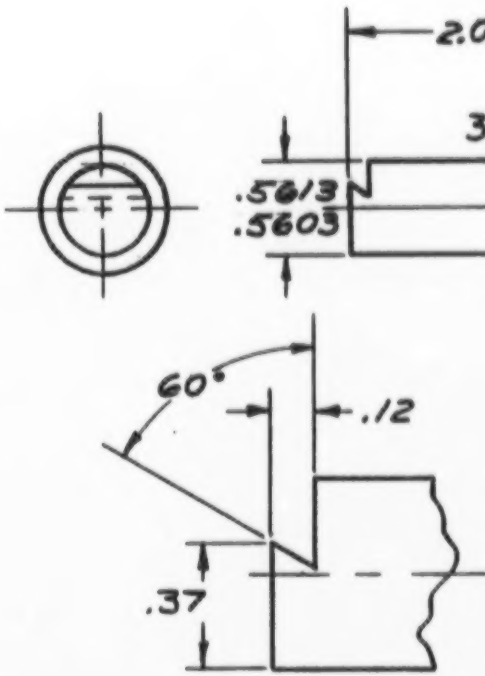


214

ANG ±		MATL: 1018	TOOL AND DIE MAKING
FRAC ±		NO. REQ. 1	
XX ±	.015	DET. NO. 7	BOTTLE CAP MOLD
XXX ±	.005		
XXXX ±		D ZINKIEWICZ	Scale: FULL — Sh 10 of 12



ANG ± 1°	MATL: 1018	TOOL AND DIE MAKING	
FRAC ±	NO. REQ. 3	CAP MOLD INSERT	
XX ± .02	DET. NO. 3	Scale: FULL	Sh 11 of 22
XXX ± .005	J PSUIK 68		
XXXX ± .0005			



2 X SIZE

217

ANG ±	2°	MATL: 1018	TOOL AND DIE MAKING
FRAC ±	1/16	NO. REQ. 1	BOTTLE CAP MOLD
XX ±	.015	DET. NO. 13	
XXX ±	.005	D ZINKIEWICZ	Scale: FULL Sh 12 of 12
XXXX ±			